# THE SANITATION
OF
# BOMBAY.

BALDWIN LATHAM, C.E.

with the Author's Compliments

# REPORT

ON THE

# SANITATION OF BOMBAY.


BY

BALDWIN LATHAM, M. Inst. C.E.,

M. I. MECH. E., F.G.S., F.S.S., F.S.I., ETC.,

PRESIDENT OF THE ROYAL METEOROLOGICAL SOCIETY.

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THE

# SANITATION OF BOMBAY.

To E. C. K. Ollivant, Esq., C.S., C.I.E.,
Municipal Commissioner, Bombay.

Byculla Club, Bombay,
13*th March*, 1890.

Sir,—

I have the honour to report to you that I have examined the condition of the existing sewers and surface water system of drainage of the city of Bombay. I have also read the documentary evidence that has been submitted to me in the form of reports to and proceedings of the Municipality; the evidence offered to various commissions; and the reports and opinions of engineers, doctors, and others who have prepared schemes or made suggestions from time to time for the sanitary improvement of Bombay. **Points considered.**

Knowing something of what has transpired in the past, and what is the present condition of the sanitary works of your city, I have deemed it expedient to dismiss from my mind all divergent opinions that have been set before the Municipality from time to time, and to commence my investigations just as if nothing had been done in the shape of sanitary work in this district; using only the evidence of actual facts which have been clearly proved, or which are supported by overwhelming evidence to guide me, in conjunction with the information I have been able to procure for myself while visiting the locality. **Divergent opinions.**

A very complete investigation into the climatic conditions of this place has been rendered necessary as having **Climatic conditions.**

a direct bearing on the nature of the sanitary works it may be necessary to construct, and also as influencing every mode of sewage disposal.

Island below high-water mark.

A large part of the Island of Bombay being below the level of high-water mark of the sea, the various questions affecting the rise and fall of the tide, the direction of sea and tidal currents, have all had to be most carefully considered.

*Climatic Conditions.*—The first consideration affecting the health of the inhabitants of any place is that of climate. In the case of Bombay, it is extremely fortunate that you possess the observatory at Colaba, where for a long series of years various meteorological data have been observed and recorded; and I cannot speak too highly of the value of such observations, and can only hope they may be long continued under the distinguished guidance of Charles Chambers, Esq., F.R.S., &c. By reference to the published records of the Colaba Observatory, augmented by the assistance of Mr. Chambers to bring the observations up to a recent date, I first directed my attention to the subject of the rainfall, in order, if possible, to determine what was the rate of fall, the quantity falling, and the frequency of the rainfall. With reference to the fall of rain, it should be observed there are probably no two spots in Bombay or elsewhere that will give identically at all times the same amount of rain. As a rule, rain increases with the elevation of the ground above the level of the sea; it has also a tendency in some places to increase as we go northward, or into colder parts of the country. The amount of rain collectable in a rain-gauge diminishes with its elevation above the surface of the ground, and as the Newman's rain-gauge at Colaba (the records from which I shall use) is 4 feet 6 inches above the ground, the actual amount of rain reaching the

Meteorological data.

Charles Chambers, F.R.S.

Difference in rainfall.

Law governing rainfall.

ground at that place will be somewhat greater than is shown by the records from that gauge. That rain does fluctuate in various parts of Bombay may be taken from the fact that the average rainfall at Byculla for 47 years (1843 to 1889), as published in the Bombay Directory, was 78·25 inches; while the average rainfall recorded at Colaba Observatory in the same years was 70·97 inches. The average rainfall of Bombay will be in excess of the record given at Colaba, and this must be borne in mind in making provision for the disposal of the rainfall.

Rainfall at Byculla and Colaba compared.

From observations carried on at Colaba, and published for the years 1847 to 1870, it is probable that if these observations were carried on for a sufficiently long period they would show that the average amount of rain that may be expected to fall in any one hour of the day would be identical, and would be about one inch. The knowledge of this fact will have a most important bearing on the subject of the surface drainage of the district.

One inch of rain per hour may be expected.

The following figures, which are given for the sake of reference, show the annual rainfall at Colaba:—

Colaba rainfall.

| | Inches. | | Inches. | | Inches. |
|---|---|---|---|---|---|
| 1843 .. | 55·24 | 1859 .. | 77·16 | 1875 .. | 78·29 |
| 1844 .. | 62·71 | 1860 .. | 62·15 | 1876 .. | 46·70 |
| 1845 .. | 54·12 | 1861 .. | 76·91 | 1877 .. | 64·73 |
| 1846 .. | 73·93 | 1862 .. | 73·63 | 1878 .. | 106·13 |
| 1847 .. | 76·00 | 1863 .. | 77·68 | 1879 .. | 61·40 |
| 1848 .. | 75·86 | 1864 .. | 45·57 | 1880 .. | 67·94 |
| 1849 .. | 114·89 | 1865 .. | 77·85 | 1881 .. | 73·04 |
| 1850 .. | 50·25 | 1866 .. | 78·44 | 1882 .. | 69·23 |
| 1851 .. | 96·07 | 1867 .. | 62·30 | 1883 .. | 90·18 |
| 1852 .. | 69·27 | 1868 .. | 62·12 | 1884 .. | 75·44 |
| 1853 .. | 62·60 | 1869 .. | 91·66 | 1885 .. | 67·91 |
| 1854 .. | 82·14 | 1870 .. | 66·21 | 1886 .. | 99·74 |
| 1855 .. | 41·18 | 1871 .. | 40·58 | 1887 .. | 94·95 |
| 1856 .. | 65·92 | 1872 .. | 76·48 | 1888 .. | 57·82 |
| 1857 .. | 51·27 | 1873 .. | 69·70 | 1889 .. | 67·84 |
| 1858 .. | 62·45 | 1874 .. | 82·18 | Average .. | 70·97 |

Hourly and daily heavy falls of rain.

The amount of rain that falls in the shortest time is also a matter of the greatest importance, in designing engineering works for dealing with flood waters. The following figures give the greatest registered fall of rain at Colaba Observatory as recorded in one hour, and in one day, and the date of the fall.

| Date of Hourly Rainfall. | Hourly Rainfall. Inches. | Date of Daily Rainfall. | Daily Rainfall. Inches. |
|---|---|---|---|
| 12/6/1847 .. .. | 4·22 | 11/6/1847 .. .. | 12·54 |
| 14/6/1848 .. .. | 2·20 | 14/6/1848 .. .. | 8·14 |
| 17/7/1849 .. .. | 1·39 | 25/7/1849 .. .. | 6·35 |
| 13/6/1850 .. .. | 1·70 | 17/7/1850 .. .. | 4·61 |
| 14/7/1851 .. .. | 1·90 | 25/8/1851 .. .. | 6·51 |
| 21/6/1852 .. .. | 1·96 | 22/6/1852 .. .. | 7·09 |
| 9/6/1853 .. .. | 2·35 | 18/6/1853 .. .. | 9·89 |
| 14/6/1854 .. .. | 1·42 | 14/6/1854 .. .. | 5·55 |
| 26/6/1855 .. .. | 1·34 | 20/6/1855 .. .. | 4·79 |
| 9/6/1856 .. .. | 1·77 | 9/6/1856 .. .. | 10·28 |
| 1/8/1857 .. .. | 1·12 | 1/8/1857 .. .. | 5·27 |
| 9/7/1858 .. .. | 1·50 | 11/9/1858 .. .. | 6·15 |
| 16/7/1859 .. .. | 2·16 | 12/6/1859 .. .. | 8·20 |
| 16/7/1860 .. .. | 1·91 | 13/6/1860 .. .. | 7·31 |
| 14/7/1861 .. .. | 2·02 | 18/8/1861 .. .. | 6·08 |
| 9/9/1862 .. .. | 3·00 | 21/6/1862 .. .. | 6·16 |
| 24/7/1863 .. .. | 1·84 | 24/7/1863 .. .. | 8·14 |
| 27/8/1864 .. .. | 1·07 | 26/6/1864 .. .. | 3·56 |
| 14/8/1865 .. .. | 1·05 | 2/7/1865 .. .. | 7·86 |
| 2/8/1866 .. .. | 2·62 | 11/7/1866 .. .. | 7·63 |
| 5/7/1867 .. .. | 1·93 | 16/7/1867 .. .. | 5·41 |
| 16/7/1868 .. .. | 1·00 | 9/8/1868 .. .. | 10·23 |
| 12/7/1869 .. .. | 1·11 | 27/6/1869 .. .. | 15·31 |
| 13/10/1870 .. .. | 1·43 | 18/6/1870 .. .. | 4·71 |
| 31/8/1871 .. .. | 1·88 | 31/8/1871 .. .. | 4·64 |
| 12/9/1872 .. .. | 4·13 | 12/9/1872 .. .. | 9·23 |
| 1873. No record. | | 24/8/1873 .. .. | 6·23 |

| Date of Hourly Rainfall. | Hourly Rainfall. Inches. | Date of Daily Rainfall. | Daily Rainfall. Inches. |
|---|---|---|---|
| 1874. No record. | | 21/7/1874 .. .. | 4·48 |
| 30/8/1875 .. .. | 1·35 | 5/9/1875 .. .. | 8·14 |
| 26/7/1876 .. .. | 1·40 | 27/7/1876 .. .. | 7·59 |
| 19/6/1877 .. .. | 3·39 | 19/6/1877 .. .. | 14·60 |
| 3/7/1878 .. .. | 1·39 | 3/7/1878 .. .. | 5·55 |
| 24/6/1879 .. .. | 2·14 | 30/7/1879 .. .. | 3·78 |
| 2/7/1880 .. .. | 2·69 | 2/7/1880 .. .. | 8·20 |
| 3/8/1881 .. .. | 1·70 | 3/8/1881 .. .. | 11·30 |
| 3/6/1882 .. .. | 2·55 | 3/6/1882 .. .. | 10·18 |
| 9/7/1883 .. .. | 1·75 | 13/7/1883 .. .. | 6·85 |
| 13/7/1884 .. .. | 2·17 | 13/7/1884 .. .. | 7·37 |
| 15/8/1885 .. .. | 3·18 | 15/8/1885 .. .. | 10·29 |
| 18/6/1886 .. .. | 2·84 | 18/6/1886 .. .. | 16·10 |
| 3/7/1887 .. .. | 2·17 | 10/9/1887 .. .. | 7·84 |
| 11/9/1888 .. .. | 2·52 | 14/7/1888 .. .. | 4·66 |
| 18/7/1889 .. .. | 1·21 | 8/7/1889 .. .. | 4·04 |
| Average .. | 2·01 | Average .. | 7·65 |

The average of the heavy hourly rainfall is 2·01 inches, and the average of all the greatest daily rainfalls is 7·65 inches. The greatest horal fall was 4·22 inches, and the greatest diurnal fall recorded was 16·10 inches. Rain falls at Colaba, on an average of 47 years, 103 days every year. The largest rainfall recorded in any one month was 52·75 inches, in July 1828. The largest quantity of rain that fell in any one year was recorded at Byculla in 1878, when 123·10 inches fell. The least amount of rain falling in any one year, according to the Byculla record, was 35·10 inches, in 1855.

*Average hourly rain, 2·01 inches.*

*Monthly rainfall.*

The following figures represent the number of days when rain may be expected to fall in each month of the year, and nearly also the yearly percentage of the total rainy days, from observations by Mr. Charles

*Rainy days expected each month.*

Chambers at Colaba Observatory during 28 years, 1847–1874.

| | | | |
|---|---|---|---|
| January .. .. | 0·2 | July .. .. .. | 27·3 |
| February .. .. | 0·1 | August .. .. | 25·8 |
| March .. .. .. | 0·1 | September .. .. | 19·0 |
| April .. .. .. | 0·3 | October .. .. | 4·3 |
| May .. .. .. | 1·9 | November .. .. | 1·1 |
| June .. .. .. | 21·4 | December .. .. | 0·3 |

The following figures, taken from the Byculla observations, show what an enormous difference may occur in the monthly rainfall at the monsoon period.

Monthly range of rainfall.

| | Wettest. | | Dryest. |
|---|---|---|---|
| May .. .. | 4·04 in 1879 | .. | None for many years. |
| June .. .. | 49·15 „ 1827 | .. | 5·70 in 1885. |
| July .. .. | 52·75 „ 1828 | .. | 4·27 in 1835. |
| August .. | 39·11 „ 1865 | .. | 3·15 „ 1855. |
| September .. | 29·65 „ 1849 | .. | 3·38 „ 1889. |
| October .. | 10·72 „ 1883 | .. | None in many years. |
| November .. | 1·87 „ 1878 | .. | Ditto. |

In order to ascertain if the rainfall is on the increase or decline, I have taken the records of the decades backwards from the end of last year, with the following result. Byculla record from Bombay Directory :—

Average of decades of rainfall.

| | Inches. | | Inches. |
|---|---|---|---|
| 1880–9 .. .. | 80·52 | 1840–9 .. .. | 75·61 |
| 1870–9 .. .. | 81·08 | 1830–9 .. .. | 72·87 |
| 1860–9 .. .. | 82·69 | 1825–9 (5 years) | 83·64 |
| 1850–9 .. .. | 66·60 | | |

The last decade is in excess of the general average of the 65 years' record (77·76 inches), but it will be observed it is less than the two preceding decades and the apparent increase in the rainfall will not account for the increase

of certain diseases in Bombay, which are known to be influenced by dampness, and to which reference will hereafter be made.

I have had abstracted from the Colaba records, the number of days in ten years, from 1878 to 1887, when the rainfall amounted to the quantities stated below:—

Quantities of rain falling.

| Year. | Under ¼ Inch per Day. | ¼ to ½ Inch per Day. | ½ to 1 Inch per Day. | 1 to 2 Inches per Day. | 2 to 4 Inches per Day. | 4 to 8 Inches per Day. | 8 Inches and upwards per Day. |
|---|---|---|---|---|---|---|---|
| 1878 | 36 | 16 | 23 | 20 | 14 | 4 | .. |
| 1879 | 56 | 20 | 14 | 15 | 6 | .. | .. |
| 1880 | 68 | 12 | 9 | 7 | 8 | 3 | 1 |
| 1881 | 64 | 17 | 13 | 8 | 9 | 1 | 1 |
| 1882 | 58 | 13 | 18 | 7 | 6 | 2 | 1 |
| 1883 | 69 | 14 | 15 | 11 | 9 | 5 | .. |
| 1884 | 50 | 26 | 18 | 5 | 8 | 3 | .. |
| 1885 | 61 | 22 | 13 | 11 | 3 | 2 | 1 |
| 1886 | 55 | 19 | 14 | 10 | 4 | 7 | 1 |
| 1887 | 53 | 16 | 17 | 11 | 11 | 4 | .. |
| Averages | 57·0 | 17·5 | 15·4 | 10·5 | 7·8 | 3·1 | 0·5 |
| Averages, 1857 to 1866 | 51·3 | 15·2 | 13·4 | 11·0 | 6·3 | 2·2 | 0·4 |

In Mr. R. Aitken's Report of 1866, a table similar to the last is given for a period of ten years, 1857 to 1866, and the averages recorded are placed below the averages of the later period. The more recent observations tend to emphasize the importance of dealing with the rain that falls at Bombay, in such a manner as to prevent the flooding of the low-lying districts, especially those below the level of the high water spring tides. Aitken's Report, 1866.

The rate at which rain falls is even greater than Rate of fall exceeds the figures given.

shown by the figures before given, for often excessive rates of fall may last less than an hour, and which, if they had continued would have greatly exceeded the horal rates given. It is the intensity of the rate of falling rain that it is most important to observe, so that adequate provision may be made in the size of all rainfall conduits, which must carry away excessive rainfall without inconvenience to the inhabitants of the district.

Effect of building, &c., on rainfall.

It should also be borne in mind that the increase in building, and paved and macadamised surfaces within the city, will tend to increase the quantity of rain which will flow off the surface.

Preservation of purity of rainfall.

Having regard to the excessive rainfalls that occur in limited periods in this district, above all things it is essential that the rain, as far as possible, shall be preserved in all its natural purity and be conducted, by itself, to the nearest natural outlet; and that, under no circumstances, shall rain be permitted to mingle with the sewage and other polluted waters of the district; and that all channels by which rain flows away in the monsoon period shall, at all times, be preserved and carefully guarded against pollution of every kind.

Disposal of rainfall.

Now we may consider what becomes of the rain that falls on Bombay. It is certain a large portion may at times flow off the surface; a further portion sinks into the ground, and during the monsoon period, replenishes the ground water; a further portion is used up by vegetation, which, in the rainy season in such climates becomes prolific; and a further portion is again evaporated.

Experiments on evaporation.

The only experiments on direct evaporation which have been made in India, to which I have access at the present time, are the result of three years, 1851 to 1853, at Colaba Observatory. Unfortunately, these experiments

were made with a form of evaporator then in vogue, which gave results very much in excess of what evaporation really is. The average evaporation in these three years, taken as described, was 89·5 inches per annum, while the rainfall for the same three years averaged 82·5 inches per annum. Of course, there are places where the evaporation exceeds the rainfall, but Bombay, on the average, is not one of them. There are years in Bombay when the evaporation has exceeded the rainfall, and which are distinctly marked by grave consequences to public health, which invariably follow such a climatic condition in unsanitary districts. I cannot give a better instance in recent times than the year 1877, which was preceded by a year the rainfall of which was very much less than the evaporation, when a death rate of 52 per thousand was recorded in Bombay, or a rate double that of some recent years.

Effect of evaporation exceeding the rainfall.

In the time of heavy falls of rain in Bombay, the amount of evaporation is very small. The Colaba observations exemplify this, for in the month of July 1851, the rainfall was 47·02 inches while the evaporation was but 3·07 inches. Dealing with the daily heavy rains of the monsoon period, evaporation would not diminish them by 0·10 inches, and may be discarded. The amount of evaporation that goes on in a place like Bombay has a material bearing on the health of the district. In the case of impure waters, whether of the ground or exposed on the surface, it is the pure water that is carried away by evaporation, leaving behind a liquid gradually, but certainly, increasing in foulness, and in the case of ground water it is further liable to pollution from the filth that accumulates in the ground with a degree of intensity depending on the length of the period over which evaporation exceeds the rainfall.

Influence of evaporation.

Annual amount of evaporation.

The probable annual amount of evaporation in a place

like Bombay, from a land surface charged with water in the subsoil, covered at times with luxuriant vegetation, and surrounded by water, I have determined by calculations based upon the temperature, the dryness of the air, and the velocity of the wind, would be about 62 inches per annum. The average amount of vapour suspended in the air of Bombay, which is the result of evaporation, would, if all collected as water, represent a column 10·6 inches high. This vapour is largely taken up from the sea that surrounds Bombay, and the effect of its presence is to modify and check the drying effects the air would otherwise have on the land, and it, consequently, becomes a sanitary agent exercising a potential influence for good.

Condensation.

*Condensation.*—In addition to rainfall, the ground in warm countries receives a certain amount of moisture from the atmosphere, depending upon the difference of temperature between the earth and the air. From experiments which I have been conducting elsewhere, it would appear that whenever the ground is colder than the atmosphere, an amount of condensation takes place, but when the atmosphere is colder than the ground, as at night, the ground parts with its moisture, and this moist air probably becomes the vehicle for conveying exhalations of a malarious character, and hence the importance of freeing the ground from every source of pollution.

Percolation.

*Percolation and Underground Water.*—Of the rain that falls in Bombay a large part at once flows off the surface of the district, but a part sinks into the ground and forms more or less the underground waters of this district. Some of the rocks of this district are impermeable to water, but even these rocks are fissured and not infrequently underlaid with porous bedding, and it is not unusual to find wells and tanks sunk into such strata yielding water. In districts covered with permeable

strata, the volume of water that is retained in the ground depends upon the lithographical character of the strata, its elevation, and mass. Porous strata in such a district as this tend to moderate floods, as they will retain a portion of the rainfall as in a reservoir, and subsequently part with it more slowly than if it had flowed off the surface of the ground, direct to the streams. As a rule, the amount of water that is lost in the ground after it has once entered it, forms, in many geological formations of a porous nature, a large percentage of the whole rainfall, and less rain passes by percolation into the ground with every additional foot of depth.

Porous strata moderate floods.

The amount of rain percolating through the ground in this case and becoming ground water, can, in the absence of observation, be arrived at by inference, and probably would never exceed on the average 9 inches in depth, during the rainy season. The rate of percolation is also influenced by the rate of the rainfall, and will be greatest in the heaviest rains. Subsoil waters rise in the ground abruptly, and decline slowly, and the water in the ground exists in two forms, as the water which is met with in sinking into the ground, usually called the free water, and the other form of water in ground is found diffused in the strata above the free water, where it is held by the capillarity of the soil, and it would be difficult to find any soil that is entirely free from moisture. When the rainy period commences, the first effect of the rain where the soil is not cracked is to saturate that part of the ground above the free waters, and when this has been accomplished, the rain then drives out the water held by capillarity, and each increment of rain percolating, displaces a portion of such water, which then becomes free water in the subsoil; and in proportion to the rain percolating after saturation has been reached, so the free waters increase,

Amount of percolation.

Subsoil water.

and with the increase of their volume, the rate of discharge of these waters from the ground also increases. All ground water may move from considerable distances, it may affect the health of the inhabitants of large areas, for this water is, as a rule, always moving from the highest to the lowest parts of a district. In districts in which the soil cracks in drying under high temperature and the influence of drought, both rain and impure waters may be carried at once from the surface into the ground water. The discharge of underground water by its natural outlets is subject to considerable fluctuation, and such waters in the low portions of this district will form part of the flood water for which it will be necessary to provide the means of removal.

Movement of ground water.

Influence of cracks.

Rain washes soil.

Rain performs a very important office in washing the soil and freeing it from impurities; but in Bombay, the rain percolating is, unfortunately, constantly augmented by impure waters flowing in open and permeable channels, which, more or less, ramify the city in all directions, and which renders the soil upon which the city stands impure, damp, and unwholesome, and is constantly polluting the underground streams of water, which, in consequence, carry a burden of disease and death into many parts of this city. From some observations that have been made for my information by your engineering staff, under Mr. Walton's directions, it has been found that all those parts of Bombay which are the most unhealthy are, without exception, those into which, in addition to their own impure waters, the polluted underground waters flowing from other districts circulate; and, probably the most unhealthy district of Bombay is that of Kamatipura. The underground waters move from every direction towards this place, and are actually used up in it; in fact, the ground waters in this particular district

R. Walton.

Ground water and health of Bombay.

were found at the time of my inspection to be absolutely lower than the sills of the lowest sluice, and some feet lower than the ordinary channels by which such waters could escape to the sea.

Dr. Cook.

Increase of phthisis in Bombay.

In perusing the papers placed before me, I find that attention has been directed by Dr. Cook to the increase of phthisis going on in Bombay, and ascribing it to the bringing in of additional water supplies, without adequate provision being made for the removal of such waters after use, and which, consequently, tended to produce a state of dampness in the soil, which condition favours the development of this class of disease. Probably this supposition may be true, but it must be observed that underground water channels, if left unobstructed, would carry away such additional water without inconvenience, but it appears to me that the most important channels by which the underground water ought to escape have been so blocked as to raise the whole level of these waters in the lowest parts of the district. Underground water obeys exactly the same law as water flowing on the surface, and I find that Major Tulloch, R.E., in his reports distinctly pointed out to the authorities that the raising of the low grounds about Bombay would raise the level of the floods over the island. What was then pointed out with reference to surface water is equally applicable to the underground waters, and it appears curious that with the filling up of the flats with kachra, which would have the effect of raising the subsoil water-level (as water always stands higher in the ground than in the open channels by which it escapes) there was an enormous and sudden increase in deaths from diseases of the respiratory organs. It may only be a coincidence, but I find that so great had been the progress made in filling up these flats in 1880 as to require a reconsideration of the surface drainage project,

Level of ground water raised.

Major Tulloch.

Effect of filling up flats.

Increase in deaths from respiratory diseases.

and at this time the deaths from respiratory diseases increased from 1974 in 1880 to 3799* in 1881, and have gone on increasing from the latter year up to the present time.† It should be clearly understood that the filling up of low damp ground does not get rid of subsoil water, but only tends to conceal and raise it, and that consequently precautions should always be taken for effectually draining all such grounds before they are filled up.

Drainage of grounds.

Effect of flood reservoir.

The presence of the existing flood-water reservoir (which might be more appropriately called a sewage reservoir) in which the waters are now kept up to a level of 84·0 on T.H.D., is, I am bound to inform you, a very serious interference with the discharge of subsoil water, and even of the surface waters of the adjacent lands. Before there was a reservoir, the waters could escape for eight months every year at the level of 73·64, which is the level of the old sills of Love Grove sluice. Now, the surface and ground waters outside the reservoir did at the period of my inspection stand at 79·0 on T.H.D.; the level of the sills at Warli sluice is 78·63, and at this level and distance from Love Grove could not provide an efficient outfall for the lands at Love Grove and those between that point and the populous part of the city. Having regard to the position of these swampy lands in reference to the prevailing winds, it is of the utmost importance to the health of the whole district that low and efficient drainage outlets should be forthwith provided, so as to properly drain all the low lands of Bombay. I find that this matter has not escaped the observation of your Medical Officer of Health, Surgeon-Major T. S. Weir, who has distinctly reported to the authorities of Bombay that if they succeed in taking away moisture,

Level of Love Grove sluices.

Swamps to windward of city.

Surgeon-Major T. S. Weir.

* Does not include phthisis. † *Vide* Table, p. 39.

they will remove one factor in the production of malaria; and he has further informed me that the most unhealthy period in Bombay is immediately after the rains commence, or the period coincident with the washing out of the ground of the accumulated filth into the subsoil water, and when the further effect of the rain percolating into the ground is to drive the impure ground air out of the ground into the habitations of the people.

Unhealthy period at Bombay.

*Wind.*—The direction, velocity, and frequency of the winds blowing must receive the fullest consideration. I have abstracted from the observations at Colaba the velocity and relative frequency of the wind for fifteen years, 1873 to 1887, and the following table gives the result.

Wind.

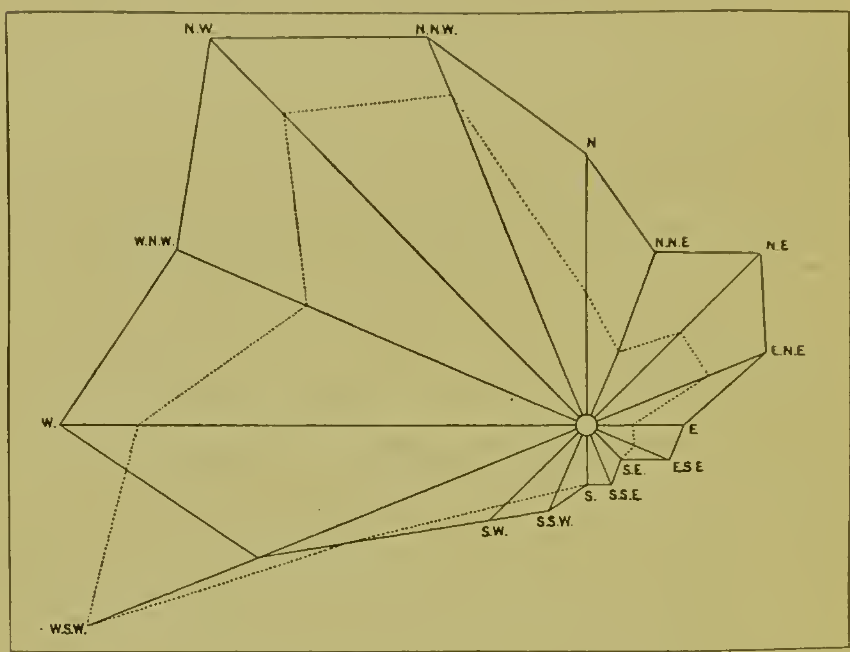
Direction, velocity, and frequency of wind.

| Direction of the Wind. | Average Daily Velocity of Wind. | Average Frequency. |
|---|---|---|
| | miles | days |
| N. .. .. .. | 12·4 | 25·7 |
| N.N.E. .. .. | 7·6 | 18·0 |
| N.E. .. .. | 12·8 | 23·5 |
| E.N.E. .. .. | 12 8 | 19·6 |
| E. .. .. .. | 4·0 | 8·8 |
| E.S.E. .. .. | 4·7 | 8·9 |
| S.E. .. .. | 4·0 | 5·3 |
| S.S.E. .. .. | 6·6 | 6·6 |
| S. .. .. .. | 6·6 | 6·3 |
| S.S.W. .. .. | 6·9 | 8·2 |
| S.W. .. .. | 11·2 | 14·0 |
| W.S.W. .. .. | 51·2 | 34·6 |
| W. .. .. .. | 43·3 | 50·5 |
| W.N.W... .. | 30·0 | 42·9 |
| N.W. .. .. | 41·7 | 52·2 |
| N.N.W. .. .. | 34·4 | 40 1 |
| Totals .. | 290·2 | 365·2 |

Average velocity of wind.

The wind, on the average, blows over Bombay 290·2 miles per day, or over 12 miles per hour, and with such an ever-moving current of air Bombay ought to be healthy, but even this wind, instead of conveying increased vigour and life to the inhabitants, may become a source of evil. By putting the velocity and frequency of the wind into a diagram, or forming a wind-rose, the influence of direction is at once discernible to the eye. In the wind-rose for Bombay, as shown below, the full line represents the

Wind-rose.




Preponderance of winds with westerly component.

frequency of the wind, while the dotted line represents the proportionate velocity of the wind, both on the average for fifteen years. The enormous preponderance of winds having a westerly component is at once seen; and by reference to the figures, and neglecting direct north and south observations, it will be found that with regard to frequency 72·78 per cent. of all the winds have a westerly component, and but 27·22 per cent. have an easterly component; with regard to the velocity or the

volume of the winds that blow over Bombay, 80·64 per cent. have a westerly component, and but 19·36 per cent. have an easterly component. The pronounced direction and volume of the winds at Bombay show how important it is that the western lands and sea should be kept free from pollution, so that the fresh winds of heaven that blow with such preponderance from the Arabian Sea shall reach the city in all their pristine purity.

Western side should be free from pollution.

I must also point out what appears from the Admiralty publications, that the winds at some periods of the year greatly influence the direction of sea currents. Winds with a northerly component tend to produce southerly sea currents, while those with a southerly component produce northerly sea currents. It will be seen from the result of the observations, that there is a very considerable preponderance of winds having a northerly component. The following figures show not only the frequency by percentage of the whole of the winds, but also the proportionate volume of such winds.

Influence of wind on sea currents.

Winds with northerly component.

| | Frequency. | Velocity. |
|---|---|---|
| Winds having a northerly component .. | 60·78 | 52·27 |
| Winds having a southerly component .. | 22·97 | 31·43 |
| Direct east winds .. .. .. .. .. | 2·41 | 1·38 |
| Direct west winds .. .. .. .. .. | 13·84 | 14·92 |
| | 100·00 | 100·00 |

A careful study of the direction of the winds will show, beyond all doubt, that so far as Bombay is concerned, if it is to get the greatest advantage from its sanitary works, it must dispose of its sewage neither on the west nor on the north of the city, and that all liability of polluting either the earth or sea should, if possible, be most carefully avoided in those directions.

Points for disposal of sewage.

Wind, effects of, on sewers.

The wind is a very important factor to consider in connection with the ventilation of the sewers, causing currents of air to traverse the sewers in various directions, and, consequently, provision should be made for preventing, as far as possible, all direct currents of air, or rather wind, passing through the sewers.

Range of temperature.

*Temperature.*—The mean temperature of the air of Bombay, as recorded at Colaba Observatory, on the average of 42 years, is 79·13°; the range of temperature in that period has varied from 100·2° as an extreme maximum to 53·3° as an extreme minimum, or 46·9°. Temperature has an important bearing on the rate at which decomposition takes place in sewage. At about the extreme minimum temperature observed here, and at all temperatures below it, sewage can be preserved fresh for an indefinite period; but at all temperatures above the minimum temperature observed here the rate of decomposition is considerably accelerated, until the temperature reaches a point near boiling, when it then exercises a preservative influence on sewage. Temperature has also some, although slight, influence on the ventilation of sewers; it has also a very potent influence on all materials used in the construction of sanitary works; even an earthenware pipe sewer is susceptible of alteration in length to a very considerable extent by changes of temperature, and sewers subject to considerable range of temperature are very difficult to maintain in a watertight condition. Sewers are subject to changes of temperature from the changes of temperature of the air, the ground, and the sewage. From observations made at Colaba on the temperature of the ground, it appears that the range of temperature of the ground is very small, and is a very favourable condition under which sewers may be constructed and main-

Temperature and ventilation.

Alteration of length of pipes.

Ground temperature.

tained watertight. The following figures give the range of the mean monthly temperature of the ground at Colaba :—

| Depth. | Period of Observation. | Mean Maximum Monthly Temperature. | Mean Minimum Monthly Temperature. | Range of Monthly Temperature. |
|---|---|---|---|---|
| inches | | ° | ° | ° |
| 20 | 1878 to 1887 | 87·5 | 74·4 | 13·1 |
| 60 | 1878 „ 1887 | 86·7 | 80·0 | 6·7 |
| 132 | 1879 „ 1887 | 84·9 | 80·9 | 4·0 |
| 144 | 1851 „ 1854 | 84·3 | 81·5 | 2·8 |

Temperature of water supply.

The temperature of the water supply of a district of course influences the temperature of the sewage; as a rule, the temperature of the water supply of a town in the mains is the temperature of the ground at the depth at which the mains are laid. On three occasions I have taken the temperature of the sewage at Love Grove pumping station, and found it was—

| | ° |
|---|---|
| 1/2/1890, at 7.30 A.M. .. .. .. .. .. .. | 75·7 |
| 3/2/1890, at 7.45 A.M. .. .. .. .. .. .. | 75·7 |
| 18/2/1890, at 6.20 P.M. .. .. .. .. .. .. | 78·4 |

The temperature of the sewage was also taken by me in the sewers of Bombay, and the figures are given at pp. 96 and 97.

Influence of sun's rays.

The temperature of the sewage of Bombay at the present time is likely to be considerably augmented by reason of the pernicious system of permitting it to be exposed in open channels to the sun's rays before it is admitted into the underground sewers, which exposure increases the liability to decomposition of the sewage, and renders the sewage very offensive when it reaches the sewers. No time should be lost in at once abolishing all open channels for sewage and conveying the whole of the sewage by proper drains

Open channels should be abolished.

to the sewers, for it must not be forgotten that sewage is a dangerous article to play with, especially in a hot country, the inhabitants of which are susceptible to a variety of intestinal and other disorders capable of being transmitted by sewage.

Area of district.

*Area of District.*—I find from the last census returns, which have been so admirably compiled, and which give a vast amount of very useful information, that the total area of Bombay is 14,231 acres. In the census return the area has been divided into a number of separate districts, for the purpose of arriving at the relative number of persons inhabiting each part of the city, and such information is absolutely requisite in grading the size of every sewer and branch sewer within the district. For the purpose of disposing of the rainfall and underground water, it is equally essential to know what is the area of each separate part of the watershed. With the assistance of your engineering staff, the disposition of the surface area of the whole district has been ascertained to be as follows :—

Division of district.

| | Acres. |
|---|---|
| Area at present draining by various outlets direct to the sea .. .. .. .. .. | 7,362 |
| Area draining or to be drained to Love Grove | 3,240 |
| Area draining to Warli .. .. .. .. | 2,308 |
| Area draining to Dharavi .. .. .. .. | 1,321 |
| Total area of district .. .. | 14,231* |

High-level areas.

Of the area draining to Love Grove 1232 acres are located above the highest water level of the sea, and the surface water could be conveyed direct to the sea. Of the area draining to Warli, 797 acres are above the highest water level of the sea; and of the area draining to Dharavi, 419 acres are above the highest water level of the sea, and

* The area of the district is given in greater detail at p. 89.

in both these cases the rainfall from these areas could be conveyed by gravitation direct into the sea; so that in the whole district more than one-third of it is high land which, at present, pours its flood waters into the low-level district, and occasionally floods it to a much greater extent than would be the case if the surface water was diverted direct to the sea from this large area of high land.

*Geology of District.*—The geology of this district when looked at from a sanitary point of view, is far more important from its hydro-geological character than from the nature of its geological formation. It will be observed from a careful study of the health statistics of Bombay, that the porous formations, like littoral concrete and alluvial and marine deposits, and even the impermeable trap formation, are more or less healthy according to elevation of the ground, and contain water in their subsoil. What has already been said in regard to percolation and ground water may be still further emphasised by the study of the geology of the district, and the relative rates of mortality on these different geological formations which have from time to time been placed before the authorities in the reports of Dr. Weir.

Geology.

Influence of geological strata on health.

Dr. Weir.

*Physical Outline of District.*—It has already been mentioned that part of Bombay lies at a lower level than high-water mark of the sea, and, as a natural consequence, special means are necessary for successfully dealing with its sewerage and drainage. The Island of Bombay appears, at no distant date, to have been a group of islands which are now joined partly by the exclusion of the sea and partly by the artificial raising of intervening low ground. If the sea should again gain admission into the island at high water, Mahim and Warli would each become separate islands, and Parel and Matongali would be joined to

Physical outline of Bombay.

Importance of excluding the sea.

Bombay by a narrow isthmus. The importance of excluding the sea is obvious, and the solidity of the structures necessary for this purpose must always receive careful attention.

Configuration of Bombay.

The Island of Bombay is formed by two parallel ranges of hills, which give a basin-shaped formation to all the island north of the esplanade, and this surface configuration points to another factor that must be considered, and that is in time of heavy rain, as the bottom of the basin is below high-water of the sea, and even, in some particular tides, below the low-water mark, therefore it is obvious that a considerable accumulation of rain may occur in the bottom of this basin at certain periods. It is absolutely essential that every means should be adopted in such a district to prevent flooding. There are large inhabited districts in England and elsewhere that are located below the high-water mark of the sea, and which have been successfully dealt with, and the principles that are well established in the drainage of these low countries must be the governing principle to be observed at Bombay. The first rule in such cases is that all flood waters from high lands, or lands above high-water mark of the sea, shall have such waters intercepted from flowing on to the low lands by being conveyed in the shortest or most convenient channels direct to the sea. The second rule, also of primary importance, is that to drain low lands successfully, the low-water level of the sea shall be brought the greatest possible distance inland.

Rules for drainage of low lands.

High lands draining into low lands.

Now, in the case of Bombay, on the eastern side of the island you have Navroji Hill, Bhandarwada Hill, and Gorapdev Hill rising from an elevation of 30 feet to over 100 feet above high-water mark, and the western slopes of these hills pour down their flood waters into the bottom of the low-lying basin, and on the western side of

the island you have Malabar Hill, Khambala Hill, and Warli Hill, rising from an elevation of 40 feet to 160 feet above high-water mark; and the eastern slopes of these hills shed their waters into the bottom of the basin. Such an arrangement, I need not say, adds enormously to the floods of the district, and it would be a great relief to all these low lands if one-third of all the flood waters could be diverted direct to the sea; this could be easily done by the construction of proper works for this purpose.

One-third of flood waters may be removed.

It appears to me, after a perusal of the original reports on the surface-water scheme, that your executive engineer, Mr. Rienzi Walton, was so much interfered with by engineering advice offered, that the principles laid down in the report of 8th March, 1875, have been departed from. In that report it was intended to deal with the high lands separately, and, according to the same report it was also proposed to construct channels in the low lands, by which the floods could have been rapidly discharged.

Interference with executive engineer, R. Walton.

In the scheme of surface-water drainage, so far as it has been carried out, the flood water from the high land, instead of being conveyed direct to the sea, is conveyed direct into the low-level district, and high and low lands are linked together to the great detriment of the low parts of the district, for it can make little difference to these low districts that the floods instead of flowing on them on one side, back up on to them on another side.

Flood waters are now conveyed into low level.

In my opinion, it is essential that the two rules to be observed for the drainage of all low lands, or lands below high-water mark of the sea, should be strictly enforced in this district.

Rules to be observed.

It is also necessary to look at Bombay with reference to its geographical position, and the formation of its coast-line as affecting the sea and tidal currents. By reference to the Admiralty charts of the west coast of Hindostan, it

Geographical position of Bombay.

will be seen that the Island of Bombay is recessed within the general coast-line and is completely land-locked on the north and east sides. The general coast-line runs from N.N.W. to S.S.E., but the western shore of Bombay projects outwards at an angle beyond the general coast-line, and the coast-line of that part of the Island of Bombay extending from the north as far south as Malabar Point, has a coast-line running from N.N.E. to S.S.W. as shown in the sketch below.

Coast-line.


Tidal observations.

*Tidal Observations.*—In the case of Bombay, the subjects of the disposal of surface water, subsoil water, and sewage cannot be considered unless we are in possession of accurate observations upon the level, length of period of the rise and fall, and the range of the tides. It is also important that the direction of the sea and tidal currents should be determined.

Grave error committed.

It appears to me, that owing to a grave error in the study of the tides and tidal flow, very erroneous con-

clusions have been drawn which have had a very material influence on the selection of the present point of outfall for the discharge of the sewage of Bombay, and which is not the point of outfall that should have been selected, had it been desired to get rid of the sewage and sewage influences once and for ever. With reference to the level of the tides, there is published every year in the very useful tide tables for Bombay, by Lieut.-Colonel M. W. Rogers, R.E., and E. Roberts, Esq., F.R.A.S., F.S.S., a table giving information on this point, from which the following figures have been abstracted :— Tide tables for Bombay.

Height of tides.

| | Feet. T.H.D. |
|---|---|
| High water, extraordinary spring tides .. | 88·42 |
| " ordinary " .. | 86·25 |
| Mean high water .. .. .. .. .. .. .. | 84·50 |
| High water, ordinary neap tides .. .. .. | 83·25 |
| Highest low water .. .. .. .. .. .. .. | 81·00 |
| Mean sea level .. .. .. .. .. .. .. | 80·16 |
| Low water, ordinary neap tides .. .. .. | 77·25 |
| Mean low water .. .. .. .. .. .. .. | 76·00 |
| Low water, ordinary spring tides .. .. .. | 74·25 |
| Mean lowest water, ordinary spring tides .. | 72·00 |
| Low water, extreme spring tides .. .. .. | 71·16 |

The extreme range of the foregoing figures is 17·26 feet. The following figures give the greatest and least range of the tide as observed at Colaba Observatory between the years 1846 and 1861. Range of tides.

| Year. | Greatest Range of Tide. Feet. | Least Range of Tide. Feet. |
|---|---|---|
| 1846 .. .. .. .. .. .. | 16·1 | 2·4 |
| 1847 .. .. .. .. .. .. | 15·1 | 2·0 |
| 1848 .. .. .. .. .. .. | 16·4 | 1·9 |
| 1849 .. .. .. .. .. .. | 15·8 | 2·2 |
| 1850 .. .. .. .. .. .. | 15·3 | 2·4 |
| 1851 .. .. .. .. .. .. | 15·9 | 3·1 |

| Year. | Greatest Range of Tide. Feet. | Least Range of Tide. Feet. |
|---|---|---|
| 1852 | 16·9 | 2·8 |
| 1853 | 14·4 | 2·4 |
| 1854 | 14·0 | 2·0 |
| 1855 | 15·9 | 2·7 |
| 1856 | 16·2 | 1·1 |
| 1857 | 10·6 | 1·0 |
| 1858 | 8·8 | 0·8 |
| 1859 | 7·0 | 1·3 |
| 1860 | 15·8 | 2·0 |
| 1861 | 15·4 | 1·0 |

Highest and lowest tides at Colaba

The observations for the years 1857 to 1859 should be rejected, as it is apparent from the observations that the tide-recording instrument was out of order in those years. Assuming that the zero of the Colaba tide-gauge was 81·21 on Town Hall datum, then the highest tide recorded at Colaba rose to 90·41 on T.H.D., and the lowest recorded tide fell to 69·81 on the same datum. The observations from the Apollo Bunder tide-gauge, which have been kindly supplied by Charles Wood, Esq., show almost analogous results to those furnished by the Colaba observations. It should also be noted that at Bombay there is a very considerable diurnal fluctuation in the level of the tides, for from September to March the tides nearest midnight are the highest, while from March to September, which covers the monsoon period, the tides nearest to noon are the highest, and this difference in the morning and afternoon tides in the months of January, June, July, and December often exceeds three feet.

Diurnal fluctuation of tides.

The following figures I have worked out from the Colaba tidal observations, and they give the height of the highest high water and the highest low water, reduced to the T H.D. during the monsoon period.

| Year. | May. | | June. | | July. | | August. | | September. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H.W. | L.W. | H.W. | L.W. | H.W. | L.W. | H.W. | L.W. | H.W. | L.W. |
| 1846 | 88·01 | 79·41 | 90·41 | 80·71 | 90·41 | 80·91 | 89·61 | 81·11 | 89·21 | 81·01 |
| 1847 | 88·31 | 80·71 | 87·01 | 79·11 | 88·41 | 80·41 | 88·61 | 80·41 | 88·81 | 80·21 |
| 1848 | 88·41 | 78·21 | 88·71 | 79·31 | 87·51 | 79·51 | 87·31 | 79·41 | 87·11 | 79·51 |
| 1849 | 88·11 | 79·01 | 88·71 | 79·01 | 89·51 | 79·51 | 88·31 | 79·91 | 87·91 | 79·71 |
| 1850 | 86·41 | 78·51 | 87·31 | 77·71 | 88·11 | 78·91 | 87·61 | 78·81 | 87·51 | 78·91 |
| 1851 | .. | .. | .. | .. | .. | .. | 87·81 | 79·01 | 87·31 | 79·21 |
| 1852 | 89·61 | 79·01 | 88·21 | 78·21 | 87·01 | 78·31 | .. | .. | 86·81 | 78·51 |
| 1853 | .. | .. | 88·81 | 80·01 | 89·11 | 79·81 | 88·61 | 80·21 | 87·91 | 80·71 |
| 1854 | .. | .. | 88·21 | 79·51 | 90·01 | 81·21 | 87·31 | 79·01 | 87·01 | 80·31 |
| 1855 | 86·11 | 77·91 | .. | .. | 88·51 | 79·91 | 88·21 | 80·01 | 87·01 | 80·51 |
| 1856 | 86·71 | 78·91 | .. | .. | 85·71 | 79·81 | 84·91 | 79·61 | 84·91 | 79·31 |
| 1860 | 87·61 | 78·81 | 86·61 | 78·91 | 87·11 | 80·01 | .. | .. | .. | .. |
| 1861 | 87·31 | 78·21 | 87·11 | 80·01 | 87·11 | 81·01 | 86·81 | 79·81 | 86·71 | 78·31 |

Height of high and low water.

NOTE.—The blank spaces are imperfect or missing records.

Accumulation of water on low lands.

The above figures clearly show that in the monsoon period you may expect such a high low water that an accumulation of the land water on the surface of the low level district must follow, unless sufficient storage is provided at a level sufficiently low to prevent flooding, or the water is at such times pumped out by mechanical means.

Time of rise and fall of tides.

The length of period of a tide, or the time of the rise and fall of a tide on an average of a large number of tides, is about equal, or the rise and fall are each 6 hours 12½ minutes; but occasionally the length of the period of the rise may be prolonged by the influence of the wind, or the time of ebb may be quickened or retarded from the same cause, and these exceptional conditions must be studied in reference to the time available for the discharge of either flood waters or sewage into the sea. Having abstracted from the records of the tidal observations taken

at Colaba during one year (1854) the time in which the tides rise and fall, the following figures give the extreme time of rise and fall of the tides in each month of that year.

| Month. | Longest Period of Rise. | | Shortest Period of Rise. | | Longest Period of Fall. | | Shortest Period of Fall. | |
|---|---|---|---|---|---|---|---|---|
| | h. | m. | h. | m. | h. | m. | h. | m. |
| January .. .. | 7 | 40 | 4 | 55 | 7 | 0 | 5 | 35 |
| February .. .. | 7 | 50 | 4 | 15 | 7 | 15 | 5 | 40 |
| March .. .. | 7 | 53 | 4 | 30 | 6 | 50 | 5 | 15 |
| April .. .. | 7 | 10 | 4 | 45 | 7 | 20 | 5 | 40 |
| May .. .. .. | 7 | 40 | 4 | 16 | 7 | 15 | 5 | 5 |
| June .. .. .. | 7 | 25 | 4 | 45 | 7 | 30 | 4 | 55 |
| July .. .. .. | 8 | 15 | 4 | 15 | 7 | 25 | 5 | 5 |
| August .. .. | 7 | 15 | 4 | 15 | 6 | 55 | 5 | 15 |
| September .. | 8 | 50 | 3 | 25 | 7 | 35 | 5 | 30 |
| October .. .. | 7 | 50 | 4 | 25 | 7 | 20 | 5 | 5 |
| November .. | 7 | 30 | 3 | 40 | 7 | 0 | 5 | 35 |
| December .. | 8 | 30 | 4 | 10 | 7 | 20 | 5 | 10 |

Ebb tides fluctuate the least.

From the foregoing figures it will be seen that there is less fluctuation on the ebb than the flood tide, and that it is a very rare occurrence for the tide to ebb for less than five hours.

Barometric pressure and level of tides.

It has been pointed out in the published Colaba reports by Mr. Chambers that, in all probability, increasing barometric pressure decreases the mean level of the sea; it is obvious, if this is the case, as the barometer is lowest in the monsoon period, that there is a tendency to get at that period a higher mean sea-level, which may amount to as much as one foot as compared with more favourable periods of the year.

Sea at low water higher than land.

The level of the tides clearly shows that there are times when the sea-level at low water is actually higher

than the surface of the lowest lands in the district, and, as has been already pointed out, provision must be made at such times for the storage of flood waters or their being otherwise dealt with, or the inevitable consequence must be the flooding of the low parts of the island. Fortunately there are two tides every day, and, owing to the diurnal differences in the rise of the tides, both tides at low water cannot be equally high, so that on one tide every day there is a chance of discharging flood waters down to a low level if sufficient provision is made for that purpose.

Time tide below certain levels.

Probably the most important factor that is required to be known in reference to the tides is the actual period of time when the tide is at or below a certain level, and this period further governs the discharging capacity of all outlets into the sea. A table has been compiled, under my instructions, in the executive engineer's office from the records of the tide at Apollo Bunder for the months of June, July, and August 1889, from which the following figures have been taken: *—

| Level of Tide. T.H.D. | Longest Period Tide below the stated Level on Fall and Rise. | Shortest Time Tide below the stated Level on Fall and Rise of Tide. | Average Time the Tide below the stated Level on Fall and Rise of Tide. |
|---|---|---|---|
| | hours | hours | hours |
| 88 | 12·41 | 12·41 | 12·41 |
| 86 | 12·41 | 9·74 | 12·36 |
| 84 | 12·41 | 7·85 | 11·16 |
| 82 | 12·41 | 6·29 | 8·26 |
| 80 | 7·85 | Nil | 5·90 |
| 78 | 6·04 | Nil | 3·39 |
| 77 | 5·51 | Nil | 2·79 |
| 76 | 4·92 | Nil | 1·34 |
| 74 | 3·61 | Nil | 0·31 |

* The details are given at pp. 82–88.

Direction of sea currents.

The directions of the sea currents in the neighbourhood of an important harbour like Bombay have not escaped attention, and for the guidance of mariners have been recorded in the 'Pilot of the West Coast of Hindostan,' while the directions of the tidal currents are shown on the charts of the harbour published in 1863, and on the most recent Admiralty charts corrected up to the present year. With reference to the sea currents, which depend entirely upon the monsoon, I had better quote the published documents:—

"The Malabar coast is indeed without anything to call a current in the north-east monsoon, except after February, when the wind takes a north-west character, and then there is a drain of the lee-current southwards, especially off Mount Dilly, increasing in March and April, when the north-westers blow stronger."

"In May variable winds take the place of north-westers, and there is little or no current along the west coast; but when the wind veers to the southward and blows fresh, it brings with it a current setting northward."

Winds produce currents in sea.

The "current setting up the coast in the Gulf of Cambay in the months of May and June, whenever the wind veers to the southward, and at the commencement of the south-west monsoon; but it is believed that the occasions are rare indeed when the current obliterates the ebb stream of Cambay Gulf. Southerly winds doubtless produce a current which tends to increase the strength of the flood stream and prolong its duration; but, one week after the rains have commenced, there is such a body of water in the freshets in many of the rivers of North Konkan and Surat, that the coast current must then have a strong southerly tendency."

Floods in rivers.

"In July, when the rains have swelled the rivers, producing great outsets, its strength is much increased;

and then, during the period of ebb tide off Bombay, that is to say, for seven or eight hours at a time, the navigator must reckon on a southerly current of at least 2 knots an hour, extending 10 miles off shore."

South-west monsoon.

"Throughout the south-west monsoon the strongest regular current of any time of the year is experienced setting southwards; below Bombay it averages about one mile per hour."

Southerly currents.

This southerly current continues along the coast from Cochin to Comorin "during September and the early part of October; for the rainy season in Malabar is not considered over till the full moon in the latter month, and the fresh waters of all the west coast rivers flow towards the southern extreme of the peninsula. The set is with the direction of the coast; the influence of the river ebbs, in general, not extending seaward as far off as a vessel should in prudence navigate along this seaboard, excepting off Bombay."

Position for outfall.

The direction of the sea currents points distinctly to a position south of Bombay as the most appropriate for a sea outfall.

Direction of tidal currents.

With reference to the tidal currents, 'The West Coast Pilot' says that the tidal wave strikes Western Hindostan from the west at right angles to the mean direction of the shore-line, or somewhere from about W.S.W. to E.N.E.

Float experiments, 1866.

It will probably be right for me now to direct your attention to the tidal float observations made in connection with Mr. Russell Aitken's drainage project of 1866. The observations were made by Mr. Jugannath Sadasewjee, C.E., with whom I have had an interview, and learnt, what appears from the observations, that they were taken with a float which obeyed the direction of the wind more readily than the tidal current. I have had access to the chart

J. Sadasewjee.

on which a number of the observations are recorded, and every one of these observations agrees with the modern charts as to the direction of the tidal currents. By reference to these early observations it will be seen that, without exception, the floats were more subject to wind force and the direction of the wind than to the tidal action, a circumstance almost entirely due to the form of float used, which, I have been informed, consisted of a barrel floating on the surface, carrying a flagstaff and flag. By referring to the observations it will be seen that the speed at which the floats travelled was always greatest out of the harbour when the wind was down the harbour, such as N.W. and N.W.N. winds; on the other hand, the rate of speed of the float out of the harbour was always the slowest when the wind was up the harbour, or S.E. and E.S.E. The force of the wind also materially affected the rate of travel of these floats: with a wind force of 1 to 2½, when the wind was N. and N.W., the floats had a rate of travel of about half a mile per hour out of the harbour; but a wind in the same direction having a force of 13½ to 16½, gave a rate of travel of 2¾ miles per hour. With S.E., E.S.E., and E. winds, varying in force from 8 to 10½, the velocity was from one-fifth to one-third of a mile per hour out of the harbour; and with S.W. and W.S.W. winds the rate of travel out of the harbour was from one-eighth to one-sixth of a mile per hour. The element of wind must not be entirely ignored in the case of a sewage outfall, as there are certain substances discharged from sewers that will float for a time on the surface of the water; and as such substances are liable to be driven on shore by the wind, it becomes very important to select a point of outfall the least likely to be influenced by the direction of the prevailing winds.

Influence of form of float.

Floats influenced by wind.

Force of wind, influence on floats.

Floating substances in sewage.

Mr. Corke. Mr. Jolley. Sir Henry Morland. Tidal currents.

I must now draw your attention to the evidence given on pages 52 to 55 of the Report of the Commission of 1877, by Mr. Corke, first assistant to the master attendant; also of Mr. Jolley, second assistant to the master attendant, pages 55 to 58, confirmed as this evidence is by Sir Henry Morland on page 66 of the same report. The evidence of Mr. Corke practically comes to this, that at the extreme end of the South-west Prongs, in 36 feet of water at spring tide, at the commencement of the flood, the set is E.S.E. ↘; as the tide covers the rocks it falls to east →, and northward ↗. At three-quarter flood the set is N.E. ↗. At the South-east Prongs, at the beginning of the ebb, the set is W. ←, and by N. to W.N.W. towards Back Bay ↖ till it extends $2\frac{1}{2}$ to $3\frac{1}{2}$ miles, and then sets W.S.W. ↙ and goes out to sea, where the set is S.W. ↙ as long as the tide lasts, and goes right out to sea, never returning into the harbour.

South-west monsoon.

Mr. Jolley's evidence was to the effect that just clear of the South-east Prongs the tides from the rivers and harbour meet, causing a commotion, in the south-west monsoon till the stronger tide carries the other away with it westerly. The stronger the freshes the more westerly the set. In strong freshes after heavy rain he had seen the set W.S.W. ↙ at a point from the inner light-ship.* At the Prongs, at flood tide, the set is E. →; at half flood E.N.E. ↗; and would tend to N.E. ↗. The ebb tide runs more westerly than the flood tide.

Point for discharge of sewage.

It appears that at one time it was the opinion of a former adviser of the Municipality that if sewage was discharged just inside the mouth of the harbour, at all states of the tide, it would be carried out to sea, and that even on flood tide the sewage would be carried out and not into the harbour. I must say that the float experiments

* This ship has been removed.

that were made certainly do not corroborate this view, and as a piece of further evidence I may draw attention to that of Dr. Blaney before the Commission of 1877, who said that he was an eye-witness of some of the float experiments (Report 1877, p. 76), and that "the floats which should have gone out with the flood came back, and with the ebb they went out."

Dr. Blaney.

Accord as to direction of tidal currents.

So far as I can find any record, all persons who are in a position to form a correct judgment are agreed upon the direction of the movement of the tides, and it is therefore with profound regret that I have to draw your attention to a report made in January 1868, not by any of your officers, but which report has been referred to and quoted over and over again against certain points being selected for a sea outfall for the sewage of Bombay. The conclusions that have been drawn from this report have, in my judgment, been the main cause of your Municipality not having hitherto solved the problem of the effectual disposal of the sewage of Bombay. It does not appear to have occurred to any person, so far as I can glean from the papers submitted to me, that this report was absolutely inaccurate, and that the currents that do occur are the very opposite of those so clearly set forth in the report, and the report in this respect is either the result of a serious mistake or of imperfect or incomplete or false information having been laid before its distinguished author. It will be seen from paragraph 12 of that report that the conclusions drawn from the float experiments conducted by Mr. Jugannath Sadasewjee, C.E., are distinctly stated to be that "the flood tide has a flow towards the sea, and they seem to indicate at the same time that the ebb tide would carry the sewage back into the harbour." And again, it is stated in the paragraph in the report before quoted, that "the only legitimate

Erroneous report on tidal currents.

conclusion which may be drawn from the experiments already made is, that if sewage is discharged at any point on the harbour side of Bombay, it will, during each tide in the months of February, March, April, and May, be brought back into the harbour by the ebb tide."

Upon such an opinion the most suitable position for a sea outfall has, in my judgment, been condemned in consequence of a very serious error in the report before referred to. How such an error can have escaped detection is inexplicable, for what person knowing Bombay could be brought to believe that the flood tide flows towards the sea instead of from it, and the ebb tide flows from the sea instead of flowing towards the sea; or, in other words, who can believe that Bombay harbour empties itself on flood tide and refills on ebb tide? To my mind the whole thing is a mistake; the full lines showing the direction of the floats as laid down on the chart have been taken to read for flood tides, as would usually be the case, but unfortunately in this case they represent ebb tides, while the dotted lines in this case represent flood tides, or the opposite of the usual practice, and in this way the error in all probability occurred. I ought, however, in fairness to the author of that report, to say that he was not in favour of an outfall on the western shores of the island, for he very properly stated what is the case, that "the western coast is in fact utterly unsuited to the purposes of an outfall."

Suitable point of outfall rejected.

Report a mistake.

Western outfall condemned.

I must report that experiments made while I have been in Bombay with proper sunk floats by Mr. Raghunath Putlaji, head surveyor of the Port Trust, and whose services have been placed at the disposal of the Municipality by George Ormiston, Esq., Mem. Inst. C.E., confirm the accuracy of all the former tidal observations to which reference has been made.

New float experiments.

G. Ormiston.

Effect of mixing action.

There is also another way in which tidal water exercises a beneficial influence in carrying away sewage, and that is its conveyance away by mixing action. When any substance like sewage or other liquid is put into a liquid that occupies a space that is regularly filled and emptied, a very large part of the liquid put in will be conveyed away by mixing action, even if there be no current. In the case of Bombay, where the relative proportion of sewage to sea water is very great, a very large percentage of all the sewage would be taken away never to return, even if it still remain sewage in sea water, which fortunately is not the case.

Description of diagram.

The annexed sketch plan (Plate 1) shows the direction of the flow of the tides. The fledged arrows on the plan, and throughout this report, indicate the direction of the flood tides, while the unfledged arrows indicate the direction of the ebb tides.

Outfall south of island.

The directions of the tidal currents in the case of a sea outfall being adopted for Bombay demand that such outfall should be located to the south of the island.

Continuous discharge of sewage.

In whatever position a sea outfall for Bombay was selected, and the sewage discharged continuously, the flood tide would bring a part of the sewage mixed with sea water back upon the island, which is not a desirable state of things. Experiments at the existing outfall show that the sewage and sea water are moved backwards and forwards by the ebb and flood tides for a considerable distance, thus tending to foul a long length of foreshore.

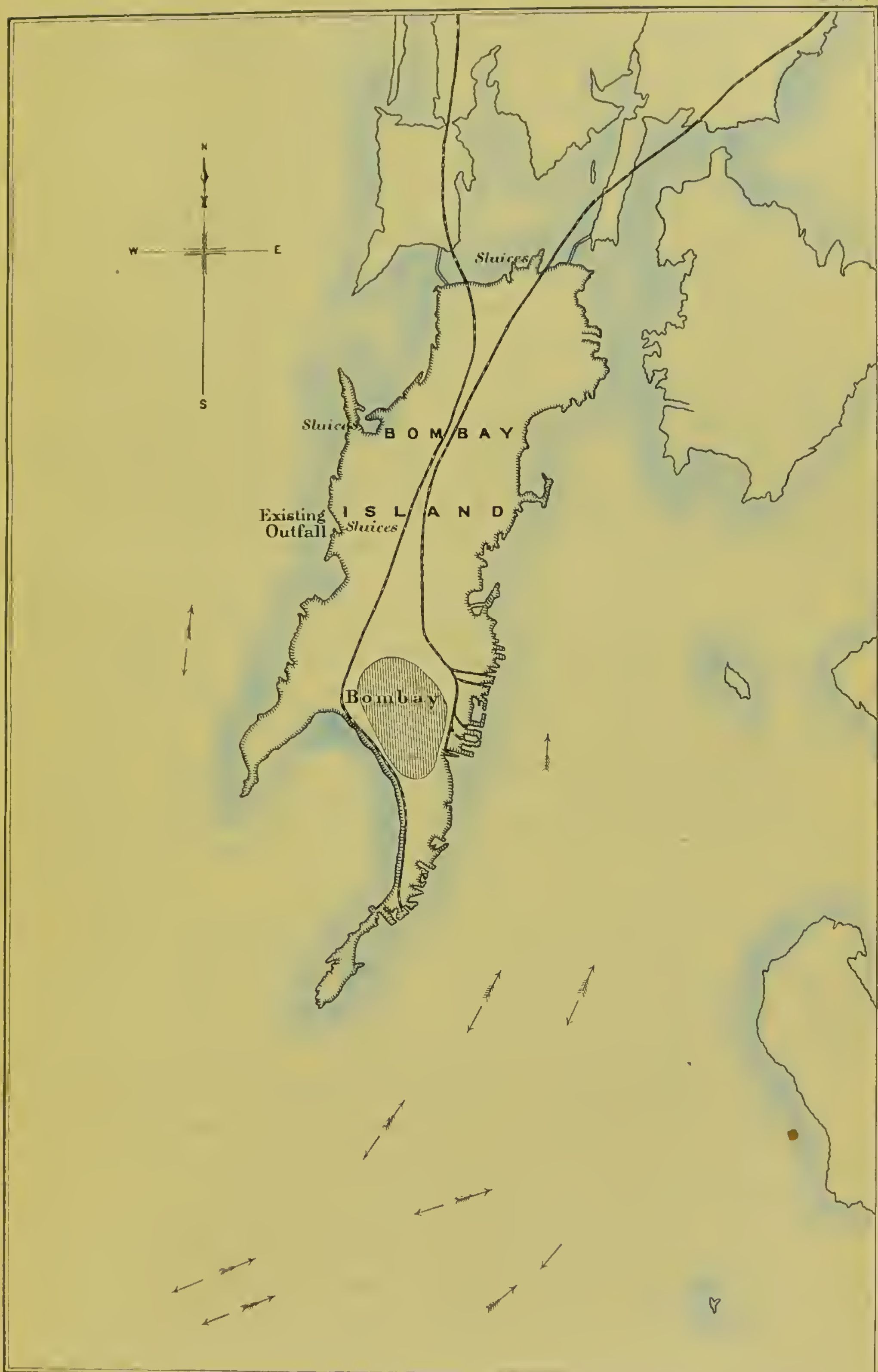
Sewage must be stored.

In order to effectually get rid of sewage at the proposed point of southern outfall the sewage should be stored either in the sewers or in a covered reservoir, and the discharge should be limited to four hours on the ebb tide only.

Discharge in four hours on ebb tide.

Reservoir principle.

The application of the reservoir principle to the present outfall would be a great improvement, as the

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To face page 36.

sewage would then only be discharged for one-third the time it is now discharged, and only while the tide is drawing off the foreshore, and consequently there would be far less length of foreshore exposed to the influence of the prevailing winds. I mention this as an improvement on the existing outfall in case a southern outfall should prove too expensive, or there should be some overwhelming objection to its construction, which, however, I must say I fail to see at the present time.

Southern outfall selected in 1865.

With reference to a southern outfall, I observe that, as long since as 1865, a Commission was appointed by the Government, and they selected an outfall at Colaba; and I find also that Major Tulloch, R.E., in his first report on Bombay sewerage, throws out a suggestion that in the event of land for sewage irrigation not being available, the site chosen for the present pumping station at Love Grove was equally applicable for diverting the sewage to Colaba.

Major Tulloch and southern outfall.

Population.

*Population.*—The determination with accuracy of the population of any place between the periods of a census is always more or less a difficult problem; it is specially difficult in towns whose population is liable to considerable fluctuation, arising from the exigencies of trade and commerce.

Determination of population by proportional mortality.

It is a peculiarly difficult problem to determine, with anything like accuracy, what is the present population of Bombay. The population of any place may, however, be very fairly arrived at from a system of proportional mortality, that is, a system of working out mortalities that has for its basis the relative numbers of births to deaths. The relative number of births and deaths occurring at any time is compared with the relative number at the period of the census when the population was known. Knowing the proportional mortality and the number of deaths, the population may be determined. Proportional

Proportional mortality.

mortality is arrived at by using a basic number which differs in every place, and which is double the death-rate at the census period. The basic number for Bombay based on the census periods of 1872 and 1881 is 57·25. Another number, called a common multiplier, is also used; this number is also taken in the census years, and is a number which, if multiplied by the number of births, when divided by the number of deaths in the census years, would give what is known as the death-rate per thousand of the population. This number in the case of Bombay, based on the two last census periods, is 39·53. Now, to find the proportional death-rate in any other year, multiply the figure found by dividing the births by the deaths with the multiplier, and take the product from the basic number, and the result will give the proportional death-rate per thousand of the population. For example, in 1888 there were in Bombay 16,760 births and 22,421 deaths. Now, $57 \cdot 25 - \left(39 \cdot 53 \times \frac{16760}{22421}\right) = 27 \cdot 8$, the death-rate per thousand, and the probable population in the middle of

Population 1888.

1888 was therefore $\frac{22421 \times 1000}{27 \cdot 8} = 806{,}510$. That this is about the proper population is evident if the increase in the figures of the births and deaths are compared.

Increase in births and deaths.

From the following figures it will be seen that between the census of 1881 and the year 1888 the births had increased 0·715 per cent., and the deaths have increased in the same period 2·585 per cent. The population in the middle of the census year, or four months later than when the census was taken, may be put down at 777,966, against the actual census figures of 773,196. If in 1888 the population had increased at the same rate as the births, then the population in the middle of 1888

| Year. | Births. | Deaths. | Published Death-rate. | Births divided by Deaths. | Proportional Mortality. | Deaths, Respiratory Diseases.* |
|---|---|---|---|---|---|---|
| 1872 | 13,135 | 18,990 | 29·46 | ·6917 | 29·91 | 1,320 |
| 1873 | 12,722 | 15,665 | 24·30 | ·8121 | 25·15 | 1,308 |
| 1874 | 12,835 | 15,496 | 24·04 | ·8282 | 24·51 | 1,535 |
| 1875 | 13,391 | 18,734 | 29·07 | ·7147 | 29·00 | 1,761 |
| 1876 | 13,625 | 20,783 | 32·25 | ·6555 | 31·34 | 1,496 |
| 1877 | 13,886 | 33,511 | 52·00 | ·4143 | 40·77 | 2,706 |
| 1878 | 14,038 | 26,999 | 41·89 | ·5199 | 36·70 | 2,452 |
| 1879 | 14,559 | 22,527 | 34·95 | ·6467 | 31·69 | 1,978 |
| 1880 | 17,247 | 21,146 | 32·80 | ·8156 | 25·01 | 1,974 |
| 1881 | 16,638 | 21,856 | 27·65 | ·7612 | 27·16 | 3,799 |
| 1882 | 15,366 | 20,468 | 25·89 | ·7507 | 27·57 | 3,402 |
| 1883 | 15,182 | 23,530 | 29·12 | ·6452 | 32·75 | 3,394 |
| 1884 | 14,637 | 22,542 | 27·29 | ·6493 | 31·58 | 3,744 |
| 1885 | 14,964 | 21,850 | 25·88 | ·6846 | 30·19 | 3,787 |
| 1886 | 14,909 | 20,074 | 25·96 | ·7427 | 27·89 | 3,810 |
| 1887 | 15,429 | 20,513 | 23·25 | ·7522 | 27·52 | 3,866 |
| 1888 | 16,760 | 22,421 | 25·16 | ·7475 | 27·80 | 4,132 |

Health statistics.

would be only 783,527; or if the population had increased at the same rate as the deaths, the population ought in the middle of 1888 to be 798,076. From these figures it will be seen that the population arrived at from the proportional mortality gives more than by either of these methods, and, consequently, the result is rather to confirm the correctness of the population in the middle of 1888. I conclude, therefore, that the population was 806,510 at the time named, and for the convenience of calculation I also assume that the population has increased equally throughout all parts of the island. This being so, the actual population in the sewered area, the sewage from which finds its way now more or less

* Does not include phthisis.

Sewered area 18 per cent. less than whole area.

to Love Grove pumping station, would be 18 per cent. less than the whole population, or 661,340. The population it would be desirable to make provision for in any new works of sewerage should be about 50 per cent. in excess of the population in the middle of the last census year, when spread over the whole district, but apportioned so as to give a small increase in the overcrowded districts, and a greater increase in those districts which are likely hereafter to still more rapidly increase, or a total provision should be made for about 1,167,000 persons.

Future population.

Value of census.

I cannot conclude this section relating to the population without congratulating the local authority on the very great care and the extremely valuable way in which the census in your city has been taken and recorded, and which, as a consequence, has greatly lightened my labours, and will very much facilitate the designing of any system of sewerage.

Sewage disposal.

*Disposal of Sewage.*—The most important matter to consider in reference to every town or city is the disposal of the sewage in an effectual, sanitary, and economical manner. The existing outfall on the western shores of the island cannot be looked upon with favour, for the reason that the direction of the prevailing winds can carry any of the noxious results that may arise towards the populated district, and, more or less, taint the air that should bring life and vigour to the inhabitants of the island. The continuous discharge of sewage in every state of the tide fouls the foreshore to some extent, which again is left dry at a certain period of the tide, thus exposing an evaporating surface of a not very desirable character. I have already pointed out that much of this objection could be got rid of by the construction of a reservoir, and only discharging on a portion of the ebb

Western outfall not favourable.

tide, or while the sea water is drawing off the foreshore. However, the existing outfall, even when provided with a reservoir, cannot be said to be a perfect outfall. At the present time sewage is carried from the existing outfall in its objectionable form, certainly as far as into Vellard Bay, and it has been reported to me by Mr. Raghunath Putlaji that on the ebb tide the sea is discoloured all along the coast for this distance from the outfall, and I have noticed that sewage does deposit in this bay, and is left in small quantities on the foreshore. There can be no doubt in my mind that owing to the nature of the coast-line, the deposit of sewage is to be found for a considerable distance all along the western shore.

Sewage in Vellard Bay.

The near proximity of the outlet for storm water, which is located about 300 yards on the ebb or lower side of the sewage outfall, also offers an opportunity of taking in sea water mixed with sewage into the existing large open reservoir whenever the replenishment of the waters in this flood lake is required.

Sewage and sea water taken together into reservoir.

The rocky character of the immediate neighbourhood of the present outfall is rather favourable for retaining matters which, under other circumstances, would be more effectually got rid of, but I am bound to say that I have seen very much worse sea outfalls than the present one at Love Grove.

Rocky shore, objections to.

The site for the Love Grove pumping station and outfall have been very well selected, having regard to its central position in respect to the whole island, and as a place at which the sewage is to be continuously discharged (putting aside the sanitary aspect of the position), it is probably as good as any other spot on the island, except, of course, the extreme southern point at Colaba.

Site of Love Grove central.

It appears that various suggestions have from time to time been made for utilising the sewage of Bombay on

No land in Bombay to which sewage could be applied.

land, so as to purify it and turn it to some useful purpose. In the case of Bombay, it is admitted that at the present time there is no land within the island to which the sewage could be applied with advantage, and it would, therefore, have to be taken to a considerable distance in order that it might be disposed of on land. My attention has been drawn to a project for utilising the sewage on lands, now partly and hereafter to be reclaimed from the sea at Kurla, a place that lies to the immediate north of the island. The method of reclamation of the land is to consist in removing the street-sweepings and garbage, called kachra, from the city, and filling up the land with it to a sufficient altitude for the purpose intended. In order to ascertain the suitability of lands so filled up for the purpose of sewage treatment, I have been supplied by the Health Department of Bombay with samples of kachra that had lain in the ground from seven to ten years, and upon examination of their physical characteristics, and being lixiviated with water, it was found that in the state it was supplied to me it would form an effectual medium for the purification of sewage; but owing to its power of retaining water, the volume of sewage capable of being purified would not be so great as with a less retentive soil.

Lands at Kurla.

Experiments with kachra.

From experiments made last year it appears that a cubic foot (*vide* Mr. S. C. H. White's report) of kachra, when wet and taken after there had been one inch of rain, weighed 42 lbs. per cubic foot. A sample taken at the present dry period of the year weighed 35·27 lbs. per cubic foot. The samples which had lain in the ground until fit to be used for sewage purposes and were completely transformed into earth weighed 72·15 lbs. per foot when excavated, so that it would take two yards of kachra to supply the permanent filling of one yard of ground. If

Weight of kachra.

it is assumed that the land at Kurla has only to be raised 6 feet, then 12 feet of kachra in depth must be put upon it, and as I understand that about 1000 tons of kachra will be collected every day, or 365,250 tons in an average year, and as each super yard of the consolidated earth weighs 1·74 tons, one acre would weigh 8421·6 tons; thus every year about 43·36 acres would be in the course of formation. I cannot advise that sewage should be applied to fresh kachra, and therefore some years must elapse before the land would be fit for the reception of the sewage. At present there are 64 acres of land upon which the kachra has been deposited sufficiently long for the purpose of receiving sewage, but this small area would be quite unsuited to deal with the present volume of sewage which is now pumped into the sea at Love Grove. For ordinary irrigation with such land as this, probably the sewage of not more than 250 people could with advantage be utilised on one acre, and as the population already drained to Love Grove is 661,340, it would require 2645 acres of land upon which to utilise the present sewage; and allowing for the land you already possess, and which is fit for the purpose of being at once utilised, and assuming 1000 tons of kachra per day to be taken to Kurla, it would require nearly sixty years to fill up sufficient area of land for dealing with the sewage at present conveyed to Love Grove.

Yearly amount of land reclaimed.

Irrigation.

Time it would require to prepare land for sewage.

If, instead of adopting the broad irrigation system, intermittent filtration combined with chemical treatment was adopted, then each superficial yard of such land, when ready for the reception of sewage, would not, in my judgment, having regard to its power of absorption, filter more than half a gallon of sewage per hour. At this rate, the present sewage being taken at eight million gallons per day, 137·7 acres would be required every

Intermittent filtration.

Area of filters.

day, and allowing for the intermittent working of the filters, five times that quantity would require to be laid out for the reception of the sewage, or 688 acres would be required for dealing with the present sewage pumped at Love Grove. This application of the sewage would be at the rate of about one thousand persons to one acre of land. Sewage in such volume could not be dealt with on such land unless it was first chemically treated in tanks to prepare it for filtration, and this chemical treatment would probably cost not less than four annas per head per annum of the population.

Chemical treatment.

Cost of treating.

Cost of filters.

To prepare land for sewage filtration it would require very efficient under-drainage and the construction of surface distributing carriers, and would, probably, not cost less than 2000 rupees per acre to fit it for the reception of the sewage. The cost of tanks for the chemical treatment of the sewage and disposing of the sewage sludge, would form a costly part of such undertaking, and would give but a slight return for the money expended.

Sewage may be treated chemically.

The sewage might be treated chemically before being passed into the sea at the existing outfall, as has been suggested, and this course certainly would be a decided improvement, but I could not recommend such a system, as both the cost of the works and working expenses would be considerable, and the establishment of large sewage works on the western side of the city would, in my judgment, be out of place, having regard to its future sanitary welfare; moreover, I could not recommend the construction of sewage precipitating works anywhere within the Island of Bombay.

Objection to sewage works.

Objection to sewage disposal at Kurla.

I have read in various reports submitted to me certain objections that have been raised in connection with the disposal of the sewage at Kurla, such as the proximity of the salt-works and the liability of tainting the water

used in the manufacture of salt with sewage effluent; the difficulty of dealing with the sewage on land in the monsoon period; and the liability of fouling the harbour by the discharge of sewage in the monsoon period in an unpurified state: I may say that all these objections are purely sentimental. Having carefully observed the effects of pouring large volumes of sewage on properly prepared land which shall be sufficient in area in proportion to the sewage and rainfall, there can be no difficulty in perfectly purifying the sewage on the land at all periods. By reference to the report of the judges of sewage farms of the Royal Agricultural Society, published in 1879, it will be seen that, in the case of the sewage irrigation farm at Croydon, over the whole farm an irrigation depth of 388·5 inches of sewage per annum has been applied in addition to an annual rainfall of 33·4 inches. In a climate like that of India there can be no difficulty in dealing with sewage on land in the monsoon period, when temperature is high and vegetation luxuriant, for, in addition to the circulation of water through the soil, the evaporation from a rapidly growing crop is enormous. From experiments which I have made in England on the evaporation from a sewage-irrigated plot of rye-grass, an amount varying from 90 inches to over 180 inches in depth per annum has been carried off; and under the conditions of an Indian climate much larger quantities would be carried off.

**Report on sewage farms.**

**Climate of India.**

**Evaporation from sewaged ground.**

At the present time, no sufficient area of land exists for the treatment of the sewage of Bombay by either of the land methods before referred to; and as in all works of a sanitary character it is desirable that the whole work should be executed and brought into operation as speedily as possible, it appears evident to me that the only proper solution of the sewage problem at Bombay is the discharge

**Proper solution of sewage problem at Bombay.**

of the sewage into the sea at the south end of the island at a point entirely clear of the coast-line, and in such a way that its discharge shall be limited to four hours on each ebb tide, and that a covered reservoir of sufficient capacity, capable of retaining one-half the full volume of the sewage, should be constructed on the foreshore at the point of outfall; such reservoir to be divided into three compartments, two of which may at present be constructed, leaving the third to be executed when the exigencies of an increased population require it. A properly constructed covered sewage reservoir at the southern extremity of the island at Colaba would not be the slightest nuisance or annoyance to any person, as the experience in the use of such reservoirs has amply demonstrated.

Construction of reservoir.

I am a very strong advocate for the application of sewage to land in inland cities and towns, and in some other cases in which there are manifest advantages in utilising the sewage, especially in all cases where it is essential that the sewage should be perfectly purified before being allowed to enter any open or underground watercourse of a country from which drinking-water may be procured.

Sewage of inland towns.

Not wasteful to turn sewage into sea.

It has been found that what might be considered a great waste, as the pouring of sewage into the sea, is not wasteful, and it is questionable if more is not indirectly got out of sewage by turning it into the sea than by applying it to land. Sewage forms the food upon which numerous minute creatures feed, and which in the wise economy of nature become the food of fishes, and fish are always found under conditions in which they find the necessary food for their existence. I need only mention that so eminent a man and agriculturist as Sir John Bennett Lawes, F.R.S., who, in conjunction with

Food for fishes.

Sir J. B. Lawes.

Dr. Gilbert, F.R.S., conducted all the investigations for the Royal Commission on the best mode of utilizing town sewage in the recent inquiry before the Thames Sewage Discharge Commission, expressed the view that the turning of sewage into the sea was probably the best mode of utilizing it. Dr. Gilbert.

In turning sewage into the sea, especially at a point like Colaba, where there is no coast-line on the ebb tide to be fouled, there is the advantage that the sewage coming into contact with certain salts in sea water, is very soon precipitated; and on this point you have the actual experience of Bombay; for when the solid sewage was turned into the harbour, it was admitted that after it had flowed about one thousand feet, no trace of the fæcal matter could be found on the surface of the water; so this will be the case with more dilute sewage let out only on the ebb tide from a number of outlet pipes, carrying it far into the sea, where it will at once mix with the sea water, and nothing further will be seen of it. The destruction of the organic constituents of sewage is very rapid in sea water, as every gallon of sea water contains about two cubic inches of oxygen which speedily oxidizes the decaying organic constituents of the sewage.

Advantages of Colaba as an outfall.

Precipitation of sewage by sea water.

Oxidation of sewage.

It might be objected that the point selected for an outfall would interfere with the approaches to the harbour, but such objection is a sentimental one, and not real, for the reason before given, as to the action of sea water on sewage. The sewage of all large towns in England which are located on the sea is, without exception, turned into the sea; and quite recently, clusters of towns and villages have constructed arterial sewers exceeding twenty miles in length, in order to take the sewage down to the sea rather than incur the trouble and expense of applying the sewage to land in their immediate neigh-

Objections to proposed outfall.

bourhood; and there is not wanting an example of a seaside town in England, the sewage of which was formerly applied to land, but it has abandoned sewage farming and turned the sewage into the sea. The town I refer to is Worthing, which, however, figures in a report I have seen since I came to Bombay, of having done exactly the reverse of what I have now stated.

Experience at Worthing.

*Kachra.*—The question of dealing with the kachra is one of very considerable importance, and one which it is just as necessary to deal with as the disposal of the sewage. My opinion on this matter is most decidedly in favour of using it to fill up and reclaim tidal lands, of which a considerable area exists at Kurla and other places; and in this way, ultimately, if sufficient land can only be reclaimed, the operation may be made to pay, or rather the city authorities would lose less than by any other means of disposing of it: and hereafter, when sufficient lands have been reclaimed, I see no difficulty, but a great advantage, in being able to water these lands with part of the sewage of the districts nearest to them. If sectional drainage and automatic pumping of the sewage of Bombay are resorted to, there will be no difficulty or great cost incurred in having the means of sending part of the sewage to land in one direction, or into the sea in an entirely opposite direction, just as may be required. It must be self-evident that if in a hot country like India it will pay to pump water for irrigation, it must pay to pump water plus manure for this purpose, and this advantage could be easily secured by the sectional system of drainage.

Mode of dealing with kachra.

Reclaim lands with kachra.

With sectional drainage part of sewage sent to land.

Pays to pump sewage.

Sewerage.

*Sewerage.*—In all districts of an urban character a large amount of filth of various kinds is produced which, if left in the midst of the population, poisons the air, earth, and underground waters, to the manifest injury

and destruction of the health of the people. To preserve the people in health means must be devised and adopted for the speedy removal of all decomposing matter from the midst of the population; and in a hot country, the more speedily these matters are removed, the better it will be for the health of the people. In a city like Bombay, where some millions of gallons of fresh water are daily brought into the city, and which by use is fouled in various ways, it is essential that the means should be provided for the removal of the waters so brought in.

Importance in hot country.

Removal of water brought into city.

Experience of various systems in different countries that have from time to time been brought into operation for conveying away either part or the whole of the polluted matter where people congregate together, has resulted in the acknowledged fact that what has been termed the English system of water carriage is superior to every other method that has been devised.

Water carriage system the best.

In Bombay the authorities have rightly considered works of sewerage necessary to secure the health and comfort of the people, and have inaugurated a system of sewers; but, unfortunately, the system is not complete, and what has been done is so misused as, in my judgment, to seriously threaten the health of the people.

Sewers misused.

The sewers of Bombay, instead of being put to their legitimate use, have been converted into underground receptacles of decomposing filth, and, instead of flowing with an ever-moving and living stream, are silted up with decaying matters, giving off deadly gases, to the positive injury of the health of the people.

State of sewers.

The following table shows the actual state of the brick sewers in Bombay, as they were found on my inspection, together with the level of the sewers and sewage, as has been ascertained by actual levelling by your executive engineer's assistants.

State of brick sewers in Bombay.

| Name of Sewer. | Length of Sewer. | Inclination as designed. | Existing inclination of invert. | Depth of Silt in Sewer. | Surface Inclination of Sewage. |
|---|---|---|---|---|---|
| | feet. | 1 in | 1 in | feet. | 1 in |
| Main outfall .. .. .. .. | 4916 | 2200 | 2048 | 3·20 | 2066 |
| Clerk Road to Arthur Road | 2352 | 1876 | 1960 | 3·65 | 3278 |
| Arthur Road to Foras Road | 3282 | 1876 | 2051 | 3·50 | 5390 |
| Foras Road to Grant Road .. | 1412 | 1543 | 1471 | 3·11 | 2447 to nil |
| Khetwadi Back Road .. .. | 604 | 1543 | 1589 | 3·20 | 2487 |
| Khetwadi Back Road to Ardeshar Dadi Street, and part Girgam Back Road .. | 2693 | 1365 | 1362 | 2·45 | 2373 |
| Girgam Back Road to Thakodwar Road .. .. .. | 688 | 1187 | 1229 | 0·81 | 3440 |
| Thakodwar Road to Shek Memn Street .. .. .. | 3484 | 1187 | 1062 | 0·66 | 2050 |
| Khetwadi Back Lane to Girgam Road .. .. .. .. | 2843 | 1100 | 1034 | 1·89 | 1788 |
| Girgam Road along Charni Road to Thakodwar Road | 2533 | 1100 | 898 | 1·45 | 1224 |
| Queen's Road to 1st Marine Street.. .. .. .. .. | 3224 | 1100 | 1459 | 1·21 | 1269 |
| Kamatipura and Bazaar Street | 897 | 981 | 886 | 1·88 | 618 |
| Clerk Road .. .. .. .. | 4937 | 1000 | 845 | 1·37 | 1345 |
| Ripon Road from Clerk Road | 4919 | 1000 | 970 | 1·15 | 1000 |
| Averages .. .. | .. | 1361 | 1347 | .. | 2200 |

Having personally inspected all the above sewers, I can vouch for their state, and their condition is expressed but imperfectly by the foregoing figures. The figures representing the surface fall of the sewage give the average fall, but in places in the sewers the sewage is so ponded up by the deposit of silt as to produce absolute stagnation.

Flow in sewers depends on surface fall of liquid.

The flow in all sewers being entirely dependent on the surface fall of the sewage, it must be evident that

anything that diminishes the fall and makes the inclination of the surface of the sewage no longer equal to the fall of the invert of the sewer, has a very pernicious effect on the sewer. All the main brick sewers have been properly designed with reference to their size and gradient, and would be self-cleansing if fairly treated, but owing to the fact that silt has been allowed to accumulate in them, the rates of inclination of the sewage have, on the average, been reduced from 1 in 1347 to 1 in 2200; this diminution of fall alone would diminish the velocity of flow in these sewers by 25 per cent., and, consequently, a sewer that would be self-cleansing with the volume of sewage that flows through it, ceases to be self-cleansing when allowed to be blocked up to the extent indicated by the foregoing figures.

Diminution in velocity of flow.

I ought, however, to except the brick sewers in the Kamatipura district from your favourable consideration, as the sewers in that district are antiquated in design, of the old London vestry style, and which I need only say have been long abolished in all districts sewered on modern lines.

Antiquated sewers of Kamatipura.

An examination of the pipe sewers, both internally and externally, shows that these sewers, with the exception of the Marine Lines sewer, are in fairly good condition, but need more attention to keep them clean. Very great care has been taken in the construction of these sewers, and the mode of jointing the pipe sewers, so as to render them as watertight as possible, and the jointing is superior to what I have seen in any other place. It is a very easy matter to find fault, but not so easy to improve a work if we take into consideration the difficulties attending the first construction of works of a novel character in a new country, inexperienced in the execution of such works, but I must say that the work of laying the pipe

Pipe sewers.

Pipes well jointed.

Novel work under new experience.

sewers does infinite credit to all concerned; and if all the houses in the respective localities were joined up with the sewers, the difficulty of keeping the sewers clean would, to a great extent, at once disappear.

Marine Lines sewer.

With reference to the Marine Lines sewer, this is a pipe sewer which, I understand, was put in to relieve a district from the nuisance of discharging sewage into Back Bay, and in order to get the sewage by gravitation into the new system of sewers, the pipe sewer had to be made to join the brick sewer level with the invert of the large brick sewer, and consequently, owing partly to the quantity of sewage, and partly to the silting up of the sewers, the lower end of the Marine Lines sewer is sewage-logged; and to remedy this state of things, the sewer would require to be lifted 2·5 feet, or the sewage might be automatically pumped, as Mr. Walton has suggested to me, into the Queen's Road sewer in such a way that the sewage may be made to flush the brick sewer in Queen's Road. Which of these methods it will be advisable to adopt can only be determined after the matter of outfall, and the future mode of raising the sewage of this district has been settled.

Flush for sewers.

Improvements that may be made.

The experience of recent years points out how improvements can be made in the sewers of Bombay; for instance, a channel at least the full depth of the sewers should be formed in the floor of every manhole. No abrupt fall of one sewer into another at the manholes should be permitted, for such an arrangement has been found to encourage the generation and escape of unpleasant effluvia from the sewers. Every endeavour should be made to prevent direct currents of air passing through the sewers, for it must be clearly borne in mind that the more air enters a sewer, the more stinking air will leave the sewers; and that self-acting valves should

Abrupt falls in sewers discontinued.

Effects of currents of air in sewers.

# EXAMPLES OF MODERN SEWERAGE WORKS.

DETAILS — MANHOLES, TUNNEL SHAFTS, VENTILATORS, FLUSHING ARRANGEMENTS, HOUSE CONNECTIONS &c.


BALDWIN LATHAM
MEM. INST. C.E.
WESTMINSTER CHAMBERS
13 VICTORIA STREET
LONDON S.W.

be introduced in certain places in the sewers to prevent back currents when the sewers are flushed.*

At the present time, while the sewers are robbed, for a considerable portion of their length, of the sewage that should flow into them, which, if admitted, would keep them in comparatively good order, this sewage is carried by the conduits that should be only used for the discharge of surface water; and in order to avoid, during eight months of the year, the nuisance of turning sewage into the sea, it is conveyed by the surface water drains, and connections have been made between these drains and the sewers in such a way that everything, including the contents of gullies which receive a large amount of road detritus which is daily blown or cast into them, is at once most improperly sent into the sewers. In the time of the monsoon, when the surface-water drains are carrying flood water containing a large amount of earth, stones, and rubbish, a volume of mixed flood water and sewage, calculated to be equal to the normal flow of the sewage, is sent into the sewers; and as the connection between the surface drains and the sewer is made below the floor of the surface-water drain and is above the sewer proper, so solid matters rolled down the bed of the surface-water drain are at once transferred to the sewers. Now, it should be known that a mixture of the solid matter of sewage and detritus from roads soon concretes in the bed of a sewer, and extraordinary measures are needed for its removal, so that if the sewers of Bombay are to be kept in good order, it is imperative they should be only used for their legitimate purpose, and at the same time the rain or flood-water drains should be used exclusively for conveying only surface waters.

Separation of surface water from sewage.

Solid matters transferred to sewers.

It appears, from an inspection of the sewage pumping

* *Vide* Plate 2, Details of Modern Sewerage Works.

station at Love Grove, and by reference to the records of pumping, and gauging the height of the sewage in the sewers, that there has been a very serious irregularity in pumping, which interferes with the proper cleansing of the sewers. The failure of the pumps at the pumping station to keep the sewage sufficiently low, so as to maintain a proper fall in the sewers is, and has been, a matter of constant occurrence. It will be obvious that if the sewage is not at all times (having regard to the volume that may be flowing through the sewers) kept sufficiently low, so that the stream of sewage shall at least flow parallel to the invert of the sewer, then the sewage is headed up, and a diminution in the rate of inclination and velocity of flow occurs which at once leads to the deposit of silt. I find, from numerous observations that have been made by your engineering staff, that the heading up of the sewage in the sewers is a matter of constant occurrence, and it is one that in future must be avoided.

Irregularity in pumping at Love Grove.

It will be advisable that a reservoir of sufficient capacity should be constructed at the present pumping station entirely below the level of the invert of the outfall sewer, in which the irregularities of flow and pumping can be adjusted.

Construction of low-level reservoir at Love Grove.

The question of the irregularity of pumping brings into prominence the condition of the present pumping machinery, and it appears to me, after indicating the power of two of the engines and comparing it with the work performed and the consumption of fuel, that the existing pumping engines are neither certain in their action, effective at work, or economical. It has been found from gaugings made in the sewers by your engineering staff, that the volume of sewage lifted by the pumps was under 52 per cent. of the capacity of the pump barrels ; this indicates an enormous loss of power, and it is a matter that requires immediate amendment.

State of pumping machinery.

Slip over 48 per cent.

I may here mention that it is not an unusual occurrence for sewage pumping engines to raise 95 per cent. of the capacity of the pumps. The valves of the pumps are too slight and flimsy to be effective, as they do not close sufficiently quickly after the engine has passed the centres. No doubt the slamming of the pump valves has led to the introduction of sniffing valves that admit a large proportion of air into the pump barrels at every stroke, and the efficiency of the engine is destroyed in order to procure quietness.

Pump valves.

Sniffing valves.

The deficiency in filling the pumps does not constitute the whole loss, as the indicator diagrams taken on the 1st of February of the present year show that the friction is very considerable, and that, consequently, the total efficiency of the pumping engines did not, on that date, exceed 36 per cent., or about one-half of what it ought to be, which means that twice as much cost is incurred for coals as ought to be expended in doing the work.

Efficiency of engines and pumps 36 per cent.

*Elphinstone Estate Sewers.*—The sewers from the Elphinstone Estate, at the time of the monsoon, discharge both sewage and rain water direct into the harbour, as there is but one system of sewers in this district, common to both rain and sewage. The outfall sewer into the harbour is not protected with a tidal flap, so that when the sewers are put in communication with the harbour in monsoon periods, the tide just as readily enters all sewers below high water as the sewage flows out. This liability to reverse currents in the sewers is very disadvantageous to them, and this part of the district will require to be resewered on the separate system.

Discharge of sewage into harbour.

Reverse currents in sewers.

*Mody Bay Reclamation.*—From Mody Bay Reclamation there is in Mandvi Street an outfall sewer which discharges sewage direct into the harbour. In this district the sewers require to be extended, and all the houses

Sewage discharged into harbour.

in the district should be connected up to the sewers, and then the sewage from this district would cease to be discharged into the harbour.

Flushing sewers.

*Flushing the Sewers.*—The arrangements provided for flushing the pipe sewers from automatic flush tanks are very good, but there are cases in which the system can be extended. No adequate provision has been made for flushing the brick sewers, and having regard to the experience that has been furnished in working the brick sewers, I am of opinion that it is very desirable that proper permanent flushing gates should be introduced into all these sewers, so as to be able to flush them with the sewage that flows through them.

Brick sewers should have flushing gates.

Ventilation of sewers.

*Ventilation of Sewers.*—From what has already been remarked, it will be seen that the question of what is improperly called ventilation of sewers must receive some attention; but that such a system of ventilation, consisting of admitting large volumes of pure air into the sewers at one or more points, and allowing it to escape again as foul air at other points, is a system that every precaution must be taken to guard against. Every sewer having an open outfall must be protected against the admission of currents of air; and what is required in all sewers is a number of vents that shall maintain the air in equilibrium within and without the sewers. Means must be taken to prevent currents of air from passing in either direction through the sewers, as these currents are controlled by the wind, and in sweeping a long length of sewer the air becomes foul. The best way of forming the vents necessary for maintaining the air of the sewers in a proper state will be by means of shafts or pipes. The ornamental shafts used for this purpose in Bombay do credit to their designer, and by an extension of such a system, and by the simple pipes carried up the houses, or

Vents required for sewers.

Pipes or shafts.

ornamental iron columns erected at the street kerb where there are no houses. In some cases the hollow iron telegraph and telephone poles would serve the purpose.

All the present gratings in the streets should be replaced by watertight covers, as the present covers may admit a large quantity of surface water in the monsoon period, and at other times the dust from the streets is drawn into them; and if the receptacles provided for catching such matters are not frequently cleared, the result is, they get into the sewers and add to the matters that should not be admitted, and which sewers are not intended to carry.

Water-tight covers for street gratings.

*Foundations of Sewers.*—I observe from the papers placed before me, that it is an allegation against the sewers of Bombay that they must be imperfect because they are not constructed on proper foundations. I have examined several lengths of pipe sewers in different parts of Bombay, the ground having been opened up for this purpose, so that the sewers could be examined with the view of ascertaining if there had been any settlement or irregularity that would indicate a deficient foundation. In every case examined the sewer was found perfect. Judging from my experience, comprising the construction of many thousands of miles of pipe sewers, I do not think it necessary for future pipe sewers in Bombay to be laid as a rule on artificial foundations. If pipe or other sewers are laid in good ground of a stable character, no amount of foundation can improve their position. I have found in modern practice that in some cases—and probably such cases occur in India—it is necessary to construct the sewers with flexible joints, so that they may not be destroyed by the movements of the ground which occur in hot countries when the ground is supplied with water from an adjacent river subject to regular rise and fall, like the

Foundations of sewers.

Foundations of sewers good.

Sewers with flexible joints.

Foundations necessary in bad ground.

river Nile. Foundations of sewers are necessary when bad ground is met with at the level at which it is intended to construct the sewer, when at a short distance below good ground may be found; and the object of the foundation in such a case is only to secure the benefit of the good ground. There are also cases where foundations are necessary in very unstable ground, such as a live peat or quicksand, which, fortunately, are not met with in the neighbourhood of Bombay.

Concrete protection for pipe sewers.

Concrete protection for pipe sewers should always be used in all sewers over 16 feet deep, constructed in loose soil; and in that case the concrete must encase the pipe, or otherwise the pipes are liable to crack and break from the load of earth placed upon them.

Pipes for sewers.

The quality of the materials used in the construction of the pipe sewers of Bombay is the very best that can be used, and like materials should continue to be used in the construction of all new pipe sewers. With reference to the materials used in the construction of brick

Quality of bricks for sewers.

sewers, only the very best bricks should be used, and the amount of water they are capable of absorbing should always be under 12 per cent. by weight, or otherwise they will imbibe sewage and give off unpleasant odours.

Portland cement should be used.

The cementing material to be used in the construction of the brick sewers should be Portland cement mortar without admixture with any other cementing material. In no case ought lime mortar, however good, to be used

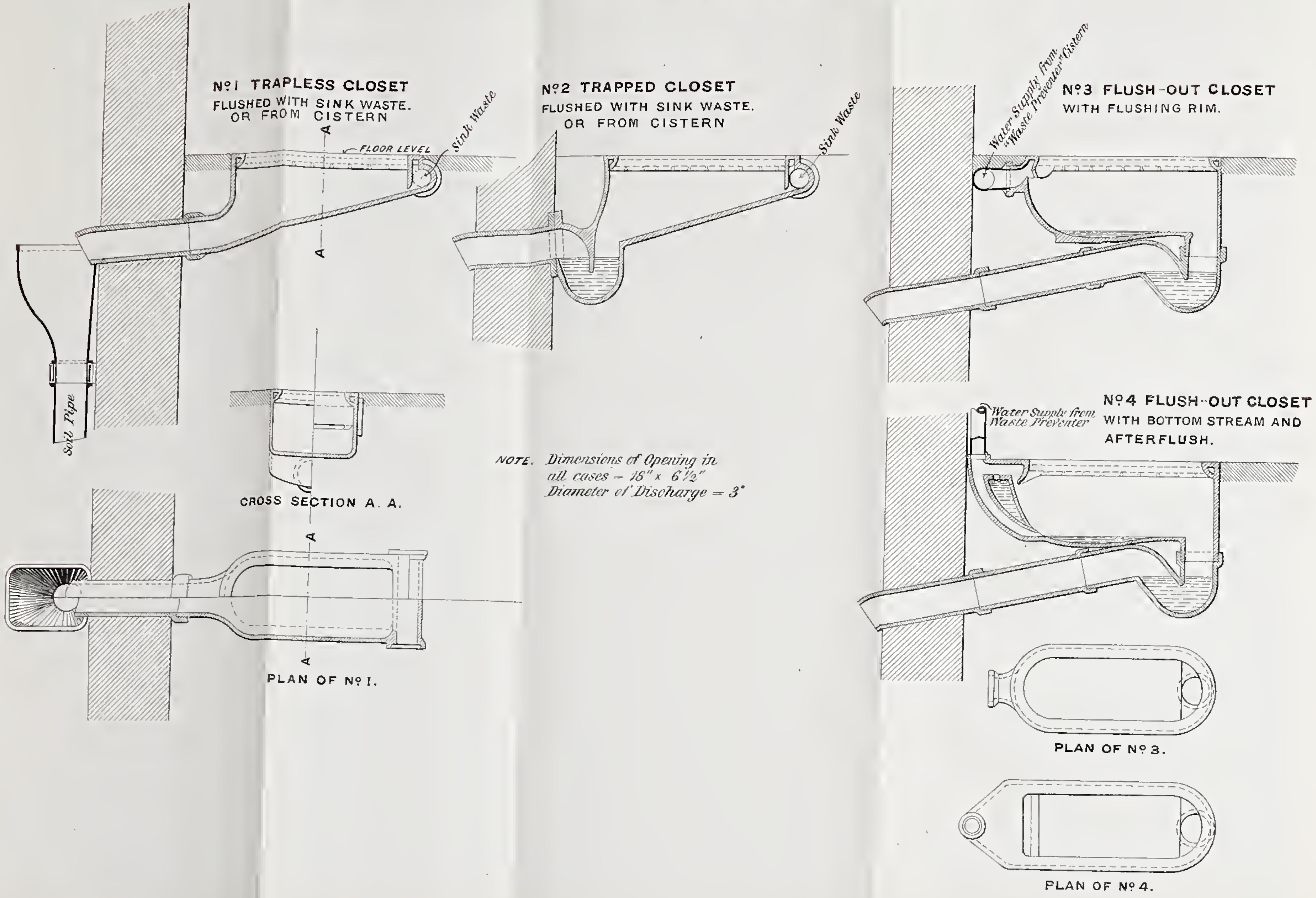
Manholes.

in the construction of sewer work. All manholes, in future, had better be built square on plan, as this shape is better adapted to make good work with the ordinary shaped bricks than is the case with circular manholes built with

Zinc pipes.

such bricks. The use of zinc for the construction of ventilating pipes from sewers should not be encouraged, but cast-iron rain-water pipes, plain or ornamental, can be substituted for zinc pipes with great advantage.

# DESIGNS FOR WATER CLOSETS FOR NATIVE USE.

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*House Drainage.*—It is essential to the proper working of a system of sewerage that a drain from every house should communicate with the sewer. The house connections should be of the simplest character. A closet adapted to the habits of the natives might be used in which the waste water from the house could be made to flush or wash it out; and such closet should discharge direct into the open hopper head of an untrapped drop pipe; and by the drop pipe the contents should be conveyed so as to fall direct into a trapped gully which should have sufficient capacity to retain improper materials from entering the sewer, and which gully will also cut off all direct communication between the sewer and the house.

House drainage.

Native closets.

The number of traps at present used in the house connections in Bombay is likely to lead to complication it is desirable to avoid. Placing the traps at the ground level will admit of better inspection and cleansing when required. In the case of houses of European residents, and others that may require perfect drainage arrangements, the plan of house connection may be similar to that adopted in England, or the insertion of an intercepting trap with an air opening between the house and the sewer, and carrying up a ventilating pipe at the head of the house drain. Every soil pipe may also be separately cut off from the drain by a direct break, as with a native closet. The sketch on the next page shows the mode in which the connection may be made between a native closet and the open hopper head of a drop pipe, and in Plate 3 I have shown a number of designs for native closets.

Complication of present arrangements.

English system.

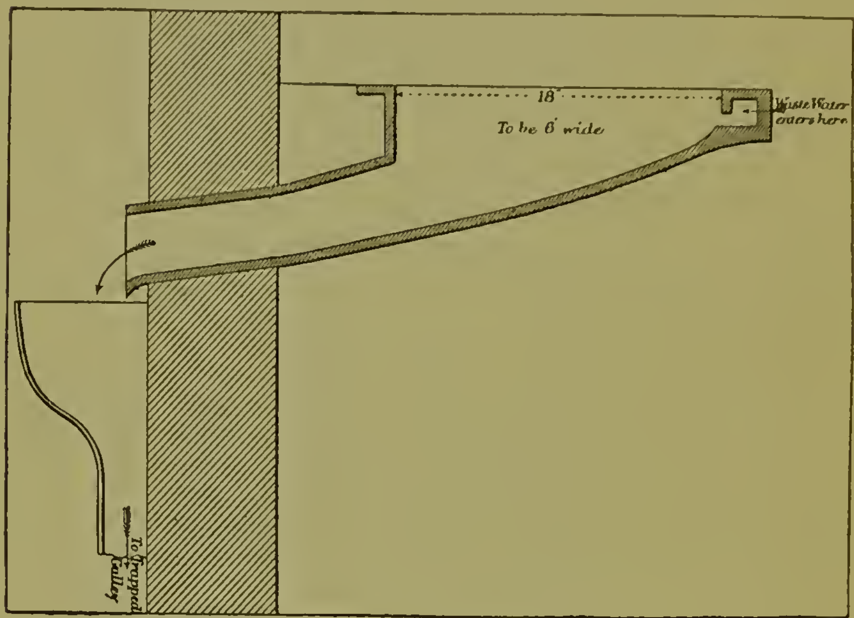
Of course, in the best houses water-closets of the English pattern will be used, and in the selection of a water-closet it will be well to reject all pan and valve closets and only use the plain hopper and wash-out

Water-closets.

closets, which are simpler and more sanitary than any form of closet fitted with moving valves or receivers.

Self-acting closets.

Any of the arrangements of native closets shown can be fitted with a treadle platform so as to make them self-acting closets.




Open space at side of house.

The present arrangement of the houses in Bombay with open spaces (gullies) at the side is such that with perfect sanitary works, a very material advantage would be secured in promoting ventilation about the buildings; but owing to the vile purposes to which these gullies are put, that which would be a great sanitary advantage is often a great nuisance, and I have not the slightest hesitation in saying is very detrimental to the health of the inhabitants. The nuisance of these gullies in a country like England would not be permitted for a single moment, and should anything like such a state of things occur, the owners of the property would be summoned before a justice of the peace and summarily dealt with, and I think

Proper administration of law required.

you require some such law and mode of dealing with these cases in Bombay, for the evil is widespread, and doubtless leads to the sacrifice of human life, which it is the object of the law to protect.

*Volume of Sewage.*—It appears that doubts have been expressed as to the volume of sewage in Bombay being sufficient to carry away all solid and liquid filth produced by the population, and, as a consequence, the admittance of fæces into the sewers was, at one time, considered a matter of doubtful expediency. At the present time the fæces collected under the Halalcore system after such collection are turned wholesale into the sewers, and the matter so collected is brought from much larger areas than the sewers which carry it away would be required to drain, so that a disproportional amount of solid matter is now brought into the sewers in some parts of the district, and is conveyed away, which is an experiment which clearly proves that drains and sewers will remove all such matters if they are only allowed to enter them under proper regulations. Dr. Weir informs me that, at the present time, the amount of fæces daily passed into the sewers of Bombay from the nightsoil depôts is as follows:— Sewage. Halalcore system. Fæces collected.

| | Tons. |
|---|---|
| From Bori Bunder Tanks .. .. .. .. .. | 73 |
| „ Kamatipura Depôt .. .. .. .. .. .. | 74 |
| „ the Flats .. .. .. .. .. .. .. .. | 39 |
| Total daily quantity .. | 186 |

The fæces under the Halalcore system are received in baskets and subsequently collected in baskets in as dry a state as possible, and after being so collected are mixed with water, in one instance with sea water as well as fresh water. They are eventually flushed out of tanks

into the sewers in order to get rid of them. I cannot speak too strongly against such a disgusting and unsanitary system; under it, you have the daily accumulation of dangerous organic matter, often near or in very close proximity to the habitation, then the collection and carrying of this matter by men and women who ought to be engaged in some more noble occupation, and, again, you have the cartage of the material through the streets to the disgust of the sensitive public, and, lastly, the repulsive operation of men entering the tanks that receive the fæces and mixing them with water. Now all this vile business can be at once dispensed with if every house is connected with the sewers, and these solid matters are distributed in detail over the whole system of sewers, instead of being admitted wholesale at particular points of the system; and by the abolition of this system a very large sum of money would be annually saved which is now expended in the collection of the fæces only of the population.

Disgusting system.

Money saved.

Use of sea water.

The use of sea water mixed with the fæces and turned into the sewers under the high temperature of Bombay leads to the escape of sulphuretted hydrogen gas, and I am bound to confess that, in the whole course of my experience, I have never seen or smelt sewers the air of which is so strongly impregnated with this disagreeable and poisonous gas.

S. Tomlinson.

The present volume of the water supply of Bombay would be sufficient to keep the sewers in good order if it was only properly conducted into them. The volume of water that now enters the sewers is known from the volume of sewage pumped at the outfall. The total volume of the whole sewage may be arrived at from the volume of the water supply. Mr. S. Tomlinson, C.E., has supplied me with information respecting the volume of water supplied and to be furnished to Bombay, and the following

statement shows the present and prospective water supply :—

| | Gallons per Day. |
|---|---|
| From Vehar reservoir by 32-inch main .. | 8,000,000 |
| " " 24-inch " .. | 3,000,000 |
| From Tulsi reservoir .. .. .. .. .. .. | 4,750,000 |
| Total present water supply .. .. .. | 15,750,000 |
| Proposed Tansa water supply, works in progress .. .. .. .. .. .. .. .. | 17,000,000 |
| Total prospective supply .. .. .. .. | 32,750,000 |

Volume of water supply.

The population of Bombay I have already given, and if the total present supply is divided by the population, 806,510, the daily volume per head of the population becomes 19·39 gallons; but for eight months in the year 2,850,000 gallons daily is taken by mill-owners and for watering streets and public and private gardens, and this does not find its way to the sewers. The actual quantity used for domestic purposes is 16 gallons per head per day, or a volume in excess of the water supplied in many towns in England in which the water-carriage system is in full operation, and working perfectly satisfactorily. At the present time, as about 18 per cent. of all the water is distributed outside the area that is sewered, a deduction of 2,322,000 gallons must be made from the daily domestic supply of 12,900,000 gallons, leaving 10,578,000 gallons per day, which upon the population of the sewered area (661,340) gives the 16 gallons per head per day. The actual quantity of sewage pumped in the week ending 25th February, 1890, was equal to an average daily quantity of 7,954,481 gallons, or at the rate of 12 gallons per head per day of the population, showing a deficiency, between the total domestic water supply of 16 gallons per head per day and the volume actually pumped as sewage, of 25 per cent. The volume of sewage

Volume of sewage.

is small compared with some towns, but it is sufficient if the sewers receive proper attention, and as the volume of the water supply will very shortly be considerably augmented, in any new sewerage works allowance must be made accordingly; an allowance should also be made in the sewers for the admittance of a small amount of rainfall in the monsoon period which cannot be diverted from the sewers.

Allowance made for rainfall.

After making allowance for water from all sources, all new sewers should be constructed to carry 6 cubic feet per head from the future prospective population, and of this volume provision should be made in the sewers for carrying one-half of the total quantity in eight hours.

In future, any small sewers constructed in Bombay may, with advantage, have such falls as to give a velocity of flow through them of three feet per second, which will make them self-cleansing when carrying sewage much laden with solid matter.

Course of outfall sewer.

If the outfall into the sea is made at Colaba, as I recommend, then such outfall sewer may run along the western shore for some distance, striking into the high land when necessary to get sufficient cover for the work, and continuing through high ground. In this way a high-level gravitation sewer may be formed all the way from above the Government House at Parel to Colaba, which would receive and discharge a considerable volume of sewage by direct gravitation.

Level of outfall sewer.

Fall of outfall sewer.

The outfall sewer may have an invert level at Colaba of 83·0 on Town Hall Datum, and, to take the sewage of the whole island, would require to be 7 feet 6 inches diameter, and have a fall of 1 in 2500; but as it passed upwards into the district its diameter would diminish while its rate of fall would increase, and, in fact, every part

of the sewer would be graded in size with reference to the amount of work it had to perform.

Sewage collected at Love Grove.

The sewage now or hereafter collected at Love Grove pumping station may be taken by the shortest route to the proposed gravitation sewer, and the sewage of all other districts abutting upon the outfall sewer that cannot be conveniently or properly drained into it by gravitation, or by gravitation to the Love Grove system of sewers, should be pumped into the high-level outfall. At present, you have before you a project to form two additional pumping stations in order to effectually deal with the sewerage of your district, one for the north district and the other for the south district. You have also before you a project for considerably extending the system of sewerage in connection with the existing sewers. I strongly advise that, at present, nothing should be done towards making any further extension of the sewers until the most important matter, the question of the outfall, has been decided; when this has been settled it will be a question for consideration as to what method shall be adopted for raising the sewage in all the present unsewered low-level districts, or districts the sewage of which will not gravitate into the existing sewers, or into the proposed gravitation sewers.

Outfall must be first decided.

Automatic pumping.

The method of transmitting power from one central station to a number of points within the district where the sewage shall be automatically pumped by means of water at high pressure, will have many advantages in your district, such as the following :—It will diminish the size, depth, and cost of sewers, manholes, and ventilators, and the sewers can have better falls so as to cause them to work more efficiently. The sewage in each district would be pumped locally, and at the level at which it is found, and, consequently, would not all be allowed to

Advantages of high presure water system.

gravitate to the lowest part of the district to be again pumped up. Only one staff of engineers and engine drivers and stokers would be required at the central station, which might be at the present pumping station at Love Grove. The water used in transmitting power can, after use, be employed for flushing the sewers, road-watering, or irrigation. The water required for the transmission of power may be collected by means of filter tunnels and land drains from the ground, and so a circulation in the underground waters towards some point outside the city would be secured, and the effect would be extremely beneficial to the health of the whole district, and so a sanitary advantage would accrue from being able to get rid of what, no doubt, has been a source of much ill health in Bombay. The high-pressure water may also be used for a number of useful purposes in the district, one of which is the extinction of fires, for, by using a combination hydrant known as the Greathead hydrant, your present low-pressure water may have all the force impressed upon it that could otherwise only be secured by steam fire engines. You could also use the power if required to pump sea water for road watering at a number of points within the district. Automatic hydraulic pumping must not be confounded with any system in which air pressure or a vacuum is produced, both of which methods have special disadvantages when applied to the raising of sewage. Under the hydraulic system a chamber is formed below the level of the streets, in which two automatic direct-acting pumping engines would be placed, which would be actuated by high-pressure water. The machines are applicable to every variation in lift, which is not the case with other systems, as all that has to be done is to grade the size of the cylinders to meet every inequality of lift throughout the district. The engines

Use of water after transmitting power.

Use of high pressure water.

System of hydraulic pumping described.

are controlled by floats, and one engine will perform all the work required from it. The second engine is used as a reserve, and the two engines are worked alternately. The floats of both machines are capable of adjustment, so that should one engine become overpowered the second would come into action of its own accord. The power generated at the central station could be transmitted through pipes to every part of the district, and of the indicated horse-power of the engines used for generating the power, on an average nearly 60 per cent. would be available and would be realised in actual work done in raising the sewage, and which by a comparison with the duty got from the present pumping engines at Love Grove, or 36 per cent., contrasts very favourably. The hydraulic machinery is of the simplest character and not unlike that which may be seen at work in the docks here, performing a variety of useful operations. Transmission of power.

By the sectional pumping, and division of the district, the risk arising from the break-down of the pumping engines is diminished, as by a proper arrangement of the sewers one or more districts may be made to relieve any section of the district in which there might be a break-down of the pumping machinery. Risk diminished by sectional pumping.

*Surface Water System.*—Owing to the liability of serious floods occurring and swamping the central portion of the island and rendering it damp and unwholesome, it is desirable that in future means should be taken for preventing, as far as practicable, the dangerous flooding of the lower parts of the district, and for providing the means of draining all low lands to the greatest possible extent. At the present time, owing to the pernicious practice of allowing the sewage that fouls the city, and the rain water that should wash the city, to become Surface water drainage. Evil of mixing sewage and rain water.

mixed and be discharged into open reservoirs and into the sea on the western or windward side of the city and also into the harbour, there is no wonder that a nuisance is created, and it is fortunate that more serious effects have not followed such utter disregard of the laws that govern the health of communities.

Complete segregation of rain water.

The local authority, by their want of action, appear to have disregarded the excellent advice that has been given to them from time to time, that there should be a complete segregation of rain water from sewage in this district, and the consequence, I have no doubt, leads to much ill-health, and certainly is admitted, on all hands, to create a serious nuisance.

Catchwater channels.

I have already drawn attention to the area of the district, and the extent to which the rainfall might be entirely diverted from the lower parts of Bombay by the construction of a system of catchwater channels which would carry the rain water from all the high-level parts of the district direct to the sea, leaving only the rainfall of the low-level districts to be dealt with.

Disposal of flood water.

In Bombay, at the present time, there are a number of ways of disposing of flood water, but the most important, as affecting the low lands in the centre of the island, and some of the low parts of the city, are the sluices at Love Grove, Warli, and Dharavi. It appears to me that the Dharavi sluices cannot be of much service for the purpose of low-level drainage, as the waters discharge into a bay into which the tidal waters can only enter through a comparatively restricted opening in the causeways and railways that cross this bay, and consequently there can never be the same range of tide in such a bay as in the open sea.* The present area drained by the

Drainage areas.

* The levels of the water in this bay and in the open sea are given at p. 81.

existing sluices, the area for discharge at each sluice, and the level of the floor of the sluice, are as follows:—

| Name of Sluice. | Area Drained by Sluice. | Level of Sill of Sluice. T.H.D. | Level up to which Area of Sluice is calculated. T.H.D. | Superficial Area of Sluice. |
|---|---|---|---|---|
| | acres | | | feet |
| Love Grove | 3240 | 73·64 | 87·64 | 964 |
| Warli .. | 2308 | 78·32 | 86·40 | 97 |
| Dharavi .. | 1321 | 80·72 | 86·88 | 95 |

Levels of existing outlets.

It should be noted that at Love Grove the floor of the existing channel between the sluices and the sea is about 2 feet higher than the sill of this sluice—a condition of things that seriously interferes with the free discharge when the sea falls below this level.

None of the sluices are of anything like sufficient capacity to deal with the flood waters of the district, and by reference to the relative areas of the watershed and the level of the sills it will be at once seen that neither Warli nor Dharavi can be of much assistance in properly draining the district, and it is important that ample means shall be provided either at Love Grove and Warli or at both places for effectually disposing of the surface waters.

Insufficient capacity to deal with flood waters.

The following table gives the capacity of the existing reservoir at Love Grove now used for storing mixed sewage and rain water:—

Level of Bottom, 77·0 T.H.D.

| Level of Water. T.H.D. | Contents. Cubic Feet | Level of Water. T.H.D. | Contents. Cubic Feet |
|---|---|---|---|
| 78·0 | 7,167,624 | 83·0 | 43,719,204 |
| 79·0 | 14,382,816 | 84·0 | 51,172,296 |
| 80·0 | 21,645,576 | 85·0 | 58,672,896 |
| 81·0 | 28,955,904 | 86·0 | 66,221,064 |
| 82·0 | 36,313,800 | 87·0 | 73,816,800 |

Capacity of existing reservoir.

Silting up of reservoir.

The level of the bottom of the reservoir is 77·0, but there is a channel of greater depth, formed in the bed of the reservoir from Clerk Road to the Love Grove sluices, which is now silted up, and to a great extent there is a deposit of solid matter mixed with sewage in the bottom of this reservoir, which on decomposing under the heat of a tropical sun, gives off gases that more or less (especially when the material is freshly deposited) spread their noxious influence for a considerable distance, and to which I understand your attention has been drawn by your medical officer of health.* No wonder that this deposit takes place and becomes a nuisance, which always must be the case under the present reservoir system, and the admittance of foul liquid to these reservoirs which carry with them solid matters liable to speedy decomposition. What happens is this:—the mixed waters are brought down the open channel from Bellasis Bridge. The floor of this channel is a few feet below the floor of the reservoir, and the channel made along the floor of the reservoir is smaller than the channel that brings the flood water down. The reservoir at all times contains more or less water, and as the channel discharges into the reservoir at Clerk Road, a sudden check in the velocity of flow occurs, and as a natural consequence down goes the solid matter, until a great accumulation of it has occurred at the Clerk Road end of the reservoir and in the channel that should have formed a drainage channel. Owing to the existence of the deposit in the reservoir it has not been deemed prudent to allow the reservoir to become dry or to lower its water to such an extent as to serve as a proper drainage outlet for the district, and hence the train of evils which I feel I have very imperperfectly described has arisen. If the local authorities

Deposit in reservoir a nuisance.

Cause of deposit in reservoir.

* *Vide* pp. 93-95.

would complete the works of sewerage by diverting all sewage from the flood channels the nuisance of the existing reservoir would disappear. Divert sewage, nuisance disappears.

As temperature favours decomposition, I may mention that on the 18th February, 1890, I had the water lowered in the reservoir, in order to ascertain the extent to which the deposit of mud had taken place, and I took the temperature at several points, from which it was found that at 4.30 P.M. on that day the water standing in the lake near the surface had a temperature of 86°·2, the mud at the bottom of the reservoir had a temperature of 83°·4, while the water flowing out of the large sluices at Love Grove at 5.10 P.M. had a temperature of 82°·5. Temperatures of water and mud from reservoir.

The mixed sewage and sea water at the present point of the sewage outfall at Love Grove, had at 5.30 P.M. a temperature of 80°.

With reference to the works of surface drainage, it appears to me that—with the exception of the suggestions made by Mr. Rienzi Walton, your executive engineer, as to the necessity of separating the rainfall of the high lands from the low lands, and the suggestions made by Major H. Tulloch, as to the enormous increase required in the existing sluices—that things have simply been more or less a matter of guess as to the quantity of rain and flood water likely to be dealt with in this district. Mr. Walton's suggestions. Major Tulloch.

The valuable statistics supplied from Colaba Observatory as to the rainfall, and the tidal diagrams at Apollo Bunder, taken during the monsoon period, and to which I have already drawn attention, will supply the means of knowing, with something like certainty, the amount of rain that may be expected, and the probable volume that will flow off, and the time available for the flow off. It will be seen from the records of the rainfall at Colaba, to which attention has been directed, that an inch of rain Data for calculating flood water and its discharge.

on the average may be expected to fall in every hour of the day, and that the average of all the heavy rainfalls is just two inches per hour.

Capacity of flood channels.

All channels for conveying flood waters at Bombay should be made sufficient to carry two inches per hour, and if so made, will be capable of dealing with the surface floods of this district, for the simple reason that a drain that will carry a uniform quantity at the rate of two inches per hour, will in a conduit of any length carry much more, as the increment of rain that enters the lower end of the channels will have passed away before the increment of rain that enters the upper end of the channel arrives at the point of outfall; and so also for the purpose of storage, such a great provision is not required, because the rain that continuously falls in one hour takes a much longer time to flow off. In the case of the Love Grove drainage area, of which the most distant point is 3·65 miles distant from the point of outfall, if we assume a velocity of 150 feet per minute as the rate at which the rain flows off the surface, and which, as a rule, would very rarely occur, then the flow from the Love Grove drainage area, having regard to the average distance the flood water would have to travel to the point of outfall, would be deferred 32 minutes, that is, rain falling in 60 minutes would have 92 minutes to flow off. In the case of Warli sluices, with the existing drainage area, the flow would be deferred 24 minutes, and at Dharivi sluices the flow would be deferred 20 minutes.

Flood channels carry more than rate of rainfall.

Flow deferred.

Time for discharge and storage of flood.

Now if it is desired to get rid of all the rain that falls during the period of one tide, and upon the ebb only of the tide, and you have to make provision for the storage of flood waters below any particular level it may be desired to store it, the actual volume required to be stored may be readily ascertained from the following figures:—

| Level above which the Stored Water must not rise. T.H.D. | Average Time of Ebb of Tide available for Discharge. | Number of Hours Flood on Average required to be stored. |
|---|---|---|
| | hours | |
| 88·0 | 6·205 | 6·205 |
| 86·0 | 6·18 | 6·23 |
| 84·0 | 5·58 | 6·83 |
| 82·0 | 4·13 | 8·28 |
| 80·0 | 2·91 | 9·50 |
| 78·0 | 1·67 | 10·74 |
| 77·0 | 1·395 | 11·015 |
| 76·0 | 0·665 | 11·745 |
| 74·0 | 0·155 | 12·255 |

It must be clearly borne in mind that the rate of discharge of flood waters is entirely dependent on the rate of fall of the tide, when sufficient area for discharge is given in the sluices. Fall of tide governs discharge.

The foregoing figures must be read in this way:—assuming it is not advisable to store flood water above the level of 82 on T.H.D., then it would be necessary to provide an area for storage sufficient to hold the water below this level, and to know the quantity for which provision must be made. From the table it will be seen that we must provide storage for 8·28 hours, or in this case we must provide at the average rate of rain in Bombay of 1 inch per hour, which would give 8·28 inches falling; but as the rain that falls in one hour has 92 minutes to flow off in the case of the Love Grove area, the actual quantity it will be required to make provision for will be $\frac{8 \cdot 28 \times 60}{92} = 5 \cdot 4$ inches, or say, after allowing for percolation, 5 inches. Now the amount of flood water on the present Bombay drainage area of 3240 acres would be Mode of calculating allowance for floods.

equal to 59,306,000 cubic feet, or a quantity that the existing reservoir, if only filled to the height given, or 82·0 on T.H.D., would not retain.* If, however, the level for storing the water was raised to 84·0 T.H.D., then, owing to the diminished period of storage, and the longer time available for discharge, the existing reservoir, assuming it could be emptied every tide, would be about the right capacity; but as the area and level of present Love Grove sluices and channels will not permit the existing reservoir being emptied in one tide, owing to the limited capacity to discharge the water, the storage becomes insufficient even at the level of 84·0 T.H.D.

Storage insufficient.

Water should not be headed up.

In my judgment the water in the reservoir never ought to be allowed to be kept up at such a high permanent level as even 82·0 on datum; and my decided opinion is that a permanent reservoir of the description you have at the present time ought to be altogether abolished, and that the system which has answered so well and effectually in the Fen districts of England, should be the method to be adopted in Bombay. Under this system, the flood water of all high lands above high-water mark should be separated from the flood waters of the low lands, and must be conveyed direct to the sea, that the low-water level of the sea shall be brought inland as far as possible. It will be a matter for future consideration if additional sluices and a deeper drainage channel should be provided at Love Grove; or if the new works, on a much larger scale, had not better be constructed at Warli. It will also be a matter for consideration if the Dharavi sluices are capable of improvement, and if improved, would aid very materially in the discharge of the flood waters, owing to the sea level being higher at this outfall than at other points on the

Mode of procedure.

New outfall sluices.

* *Vide* p. 69 for capacity of reservoir.

coast,* and so the Warli new sluices may, in all probability, have to provide for the drainage of all the district now very imperfectly served both by Love Grove and the Dharavi sluices.

Warli sluices.

I am of opinion that new and improved sluices are required at Warli, and that the sluices should be built on the solid rock foundation close to the sea front, and that when the new sluices and channels are complete the old sluices should be altogether abolished.

Mode of drainage must be determined.

The question of the construction of new sluices and the getting rid of flood waters, and providing efficient drainage for the low lands is urgent; but before the work can be undertaken it must be definitely settled what is to be done with reference to the interception of the flood waters from all the area above high-water mark, or about one-third the whole area of the watershed, and which, if not determined, will lead to considerably greater cost being incurred in order to make provision for its storage and discharge, and greater liability to future floodings.

Level of sills of new sluices.

In order to get the full discharging capacity of the proposed new sluices, it must be borne well in mind that their sills should be at least four feet below low water of spring tides, or at about the level of 68·0 on T.H.D.; and that the waterways of the sluices shall be sufficient to discharge all the water stored in one tide, together with the waters that may flow down while the flood water is running out.

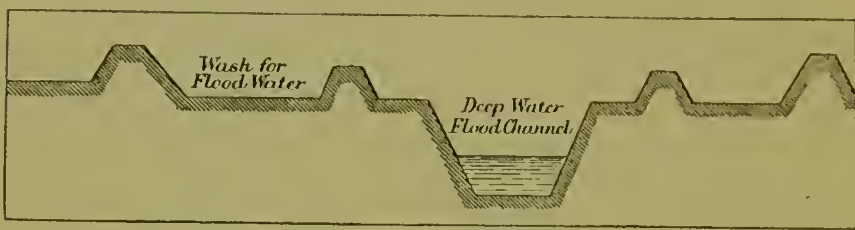
Capacity of flood channels.

The low-water drainage channels for conveying the flood waters to the sluices shall be deep and capacious, sufficiently so to carry off all flood waters or retain a moderate flood; that excessive flood waters shall be stored in washes at either side of the flood channel, with arrangements for admitting these waters into the washes

Washes provided for the floods.

* *Vide* p. 81, level of sea, Bandora Creek.

when, and not until, the flood channel is full, and for discharging the water into the channel so that it shall be retained in the washes for the shortest possible time, and then only the purest water overflowing the small embankment shall be admitted in the washes. These washes for at least eight months every year would become cultivated land, and they should be cultivated as soon as the monsoon season is over. The sketch below shows the general arrangement.




No alteration would be needed in the present Love Grove sluices, which have been well designed. Owing to the occasional level of low water of the sea it will be found, if it is desired at all times in the rainy season to keep the water on the low land or in the channels provided for its discharge below the level of 80·0 T.H.D., that this could only be secured by pumping, or the provision of inordinate storage. As pumping would be a very expensive matter, it should not be undertaken until the other works that have been suggested have been carried out, for it is quite within the probability of chance that a heavy rain may occur when there is no storage room available, and a high low water happen at the same time, which are the conditions necessary to produce a flood.

Pumping may be necessary.

I am of opinion that if the deep water channels are cut as I propose, the western side of Bombay will be effectually drained and rendered very healthy.

Bombay effectually drained.

*Cleansing Sewers.*—I must now draw your attention to the absolute necessity for constant vigilance in cleansing

Importance of cleansing sewers.

all sewers, and that it is of the utmost importance you should have a sufficient staff and labourers trained for this special service, so that all works of sewerage and surface drainage shall be maintained in an efficient state of repair and cleanliness.

*Execution of Works.*—With reference to the execution of the proposed works, it is important that those who have charge of the project should be able to give to it their undivided attention. You possess in Mr. Rienzi Walton, M. Inst. C.E., a gentleman who has had very considerable experience in the design and execution of works of sewerage, and whose experience in these matters will be invaluable in carrying out any additional or new undertaking; but you cannot expect him to do good service on the proposed works if he is not relieved from his ordinary duties of executive engineer, and I should suggest that he should be put on special duty for the purpose of carrying out the scheme, and should make his own selection of the officers to serve under him, and then he will be made entirely responsible for the proper carrying out of the works.

Recommendation as to engineer.

R. Walton.

*Estimates.*—I have not had time to prepare any estimates of the probable cost of the proposed works, as the amount of labour involved in this investigation has been very prolonged and arduous. Before any estimates could be prepared, surveys of the district will require to be made, which will involve an amount of time which I have not now at my disposal; but I may say that I shall be very happy to assist the Municipality at any future time, and to answer any inquiries that may be made respecting any part of the proposed undertaking, or to give any explanations or further information, if the communications are addressed to me at Westminster; or if they can stand over until the latter part of this year

Estimates.

Surveys required.

Will assist at any future time.

I will then deal with them, when I hope to be here for other purposes.

Acknowledgment for services rendered.

Before concluding my report, I desire to express my thanks to all those persons who have assisted me in the prosecution of my inquiries, and to say how greatly I have appreciated their services; and in order that their valuable aid may not be forgotten, I desire to put on record that my thanks are due to Charles Chambers, Esq., F.R.S., for the valuable meteorological data and tidal observations taken at Colaba Observatory; to Captain Hext, Director of the Indian Marine, for a chart of the coast of Bombay; to Charles Wood, Esq., Assistant Superintendent in charge of tidal and levelling operations, for tidal diagrams from Apollo Bunder; to W. C. Hughes, Esq., Mem. Inst. C.E., Secretary to the Government, for loan of reports; to George Ormiston, Esq., Mem. Inst. C.E., Engineer of the Bombay Port Trust, for assistance in making float observations; and to his assistant, Mr. Raghunath Putlaji, Head Surveyor, Port Trust, for conducting the tidal float observations; to David Gostling, Esq., F.R.I.B.A., for various reports connected with the improvement of the racecourse at Bombay, and other matters of a sanitary character; to Rienzi Walton, Esq., Mem. Inst. C.E., Executive Engineer for the Municipality, for the information I have received in connection with my inquiries, and his attention and courtesy at all times; to James W. Smith, Esq., Mem. Inst. C.E., Deputy Executive Engineer, for general information given me in connection with the present and proposed sewers of Bombay; to S. Tomlinson, Esq., A.M.I.C.E., for information referring to the quantity of water flowing off the ground at Vehar and Tulsi, and the distribution of water within the City; to Surgeon-Major Weir, Health Officer of Bombay, for various health statistics; to Mr. A. Baker, Inspector of

Sewers; Mr. J. D. Nadarsha, L.C.E., Acting Head Surveyor to the Executive Engineer; Mr. P. P. Vagh, Head Clerk to the Executive Engineer; and to Mr. Gaupatrao Shridar, Head Clerk, Registration of Births and Deaths.

I have appended to the Report a number of documents that have been prepared in the course of my inquiries, and others to which I have referred and which it is advisable should be placed on record for future reference. Appendix to Report.

In conclusion, I must not omit to mention the assistance I have derived, during the course of my investigations, from the perusal of the careful and explicit reports you have made from time to time, for the information of the Municipality on questions relating to the sewerage and drainage of Bombay, and which are invaluable as records of facts, and which show your perfect knowledge of all matters relating to these most important subjects; and it is, therefore, with profound regret that I learn you are about to retire from your important office at this very critical time, when your long experience and special knowledge would be of so much value to the community. E. C. K. Ollivant's reports.

I have the honour to be, Sir,

Your obedient servant,

BALDWIN LATHAM,

M. Inst. C.E., M.I.M.E., F.G.S.,
F.S.S., F.S.I., &c.,
President of the Royal Meteorological Society.

# APPENDIX.

STATEMENT SHOWING THE LEVELS OF THE TIDE as observed hourly on the 8th March, 1890, near the B.B. and C.I. Railway Iron Bridge over Bandora Creek.

| Hours of Day. | Reduced Levels of the Surface of Water. | Remarks. |
|---|---|---|
| $6\frac{1}{4}$ A.M. | 82·85 | Observation taken at $6\frac{1}{4}$ in morning. |
| 7 ,, | 82·74 | ,, ,, 7 ,, |
| 8 ,, | 82·60 | ,, ,, 8 ,, |
| 9 ,, | 82·43 | ,, ,, 9 ,, |
| 10 ,, | 82·33 | Tide commenced at 10 ,, |
| 11 ,, | 82·67 | Observation taken at 11 ,, |
| 12 | 83·08 | ,, ,, 12. |
| 1 P.M. | 83·50 | ,, ,, 1 P.M. |
| 2 ,, | 83·85 | Tide commenced to subside at 2 P.M. |
| 3 ,, | 83·45 | Observations taken at 3 P.M. |

HOURLY OBSERVATIONS OF TIDE taken on 8th March, 1890, at Wellington Pier from 6 A.M. to 6.10 P.M.

| Hours. | Reduced Levels of Surface of Water. | Remarks. |
|---|---|---|
| 6 A.M. | 75·20 | |
| 7 ,, | 75·53 | |
| 8 ,, | 76·62 | |
| 9 ,, | 78·62 | |
| 10 ,, | 81·62 | |
| 11 ,, | 84·12 | |
| 12 | 85·62 | |
| 1 P.M. | 85·70 | |
| 2 ,, | 84·12 | |
| 3 ,, | 81·45 | |
| 4 ,, | 78·28 | |
| 5 ,, | 75·86 | |
| 6.10 ,, | 74·86 | |

Statement showing the Average Time the Tides in Bombay Harbour were below the given Levels in the Months of June, July, and August 1889.

| Levels. | Average Time. |
|---|---|
| 88 | 12·41 |
| 86 | 12·36 |
| 84 | 11·16 |
| 82 | 8·26 |
| 80 | 5·90 |
| 78 | 3·39 |
| 77 | 2·29 |
| 76 | 1·34 |
| 74 | 0·31 |

Statement showing the Time the Tides in Bombay Harbour were below the given Levels in the Months of June, July, and August 1889.

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours | hours | hours | hours | hours | hours | hours | hours | hours |
| June 1 | 12·41 | 12·41 | 9·60 | 6·92 | 4·84 | 1·35 | Nil | Nil | Nil |
| " 2 | 12·41 | 12·41 | 10·98 | 8·64 | 6·91 | 5·10 | 3·97 | 2·74 | " |
| | 12·41 | 12·41 | 12·41 | 6·79 | 4·35 | Nil | Nil | Nil | " |
| " 3 | 12·41 | 12·41 | 12·41 | 8·45 | 6·57 | 4·42 | 3·19 | 1·50 | " |
| | 12·41 | 12·41 | 12·41 | 6·95 | 3·81 | Nil | Nil | Nil | " |
| " 4 | 12·41 | 12·41 | 12·41 | 8·75 | 6·69 | 4·27 | 2·54 | " | " |
| | 12·41 | 12·41 | 12·41 | 7·31 | 4·12 | Nil | Nil | " | " |
| " 5 | 12·41 | 12·41 | 12·41 | 6·92 | 6·18 | 2·79 | " | " | " |
| | 12·41 | 12·41 | 12·41 | 6·79 | Nil | Nil | " | " | " |
| " 6 | 12·41 | 12·41 | 12·41 | 7·94 | 4·85 | " | " | " | " |
| | 12·41 | 12·41 | 12·41 | 8·12 | 4·09 | " | " | " | " |
| " 7 | 12·41 | 12·41 | 12·41 | 7·87 | 4·31 | " | " | " | " |
| | 12·41 | 12·41 | 12·41 | 8·39 | 5·39 | " | .. | .. | " |
| " 8 | 12·41 | 12·41 | 12·41 | 8·05 | 4·45 | " | Nil | Nil | " |
| | 12·41 | 12·41 | 12·41 | 8·91 | 6·31 | 3·80 | " | " | " |

STATEMENT—*continued.*

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours | hours | hours | hours | hours | hours | hours | hours | hours |
| June 9 | 12·41 | 12·41 | 12·41 | 7·40 | 4·32 | 1·48 | 1·89 | Nil | Nil |
| | 12·41 | 12·41 | 11·20 | 8·61 | 6·78 | 4·97 | Nil | ,, | ,, |
| ,, 10 | 12·41 | 12·41 | 9·78 | 7·22 | 5·10 | 2·02 | 4·01 | 2·82 | ,, |
| | 12·41 | 12·41 | 10·25 | 8·32 | 6·88 | .. | Nil | Nil | ,, |
| ,, 11 | 12·41 | 12·41 | 8·80 | 6·75 | 5·07 | 5·40 | 4·61 | 3·76 | 1·21 |
| | 12·41 | 12·41 | .. | .. | .. | 2·75 | Nil | Nil | Nil |
| ,, 12 | 12·41 | 12·41 | 9·79 | 8·22 | 6·89 | 5·54 | 4·03 | 4·31 | 2·69 |
| | 12·41 | 12·41 | 8·32 | 6·71 | 5·08 | 3·09 | 1·41 | Nil | Nil |
| ,, 13 | 12·41 | 12·41 | 9·51 | 8·34 | 7·12 | 6·04 | 5·45 | 4·72 | 3·22 |
| | 12·41 | 12·41 | 8·06 | 7·12 | 5·15 | 3·38 | 2·15 | Nil | Nil |
| ,, 14 | 12·41 | .. | 9·51 | 8·21 | 7·08 | 6·02 | 5·47 | 4·89 | 3·61 |
| | .. | .. | 7·21 | 6·58 | 5·27 | 3·61 | 2·55 | Nil | Nil |
| ,, 15 | 12·41 | 12·41 | 9·50 | 8·22 | .. | 6·03 | 5·51 | 4·92 | 3·58 |
| | 12·41 | 12·41 | 8·02 | 6·60 | 5·23 | 3·72 | 2·72 | Nil | Nil |
| ,, 16 | 12·41 | 12·41 | 9·50 | 8·17 | 7·02 | 5·93 | 5·35 | 4·72 | 3·25 |
| | 12·41 | 12·41 | 8·33 | 6·75 | 5·21 | 3·59 | 2·60 | Nil | Nil |
| ,, 17 | 12·41 | 12·41 | 9·82 | 8·22 | 6·98 | 5·69 | 5·00 | 4·21 | 2·45 |
| | 12·41 | 12·41 | 9·09 | 7·08 | 5·55 | 3·89 | 2·78 | Nil | Nil |
| ,, 18 | 12·41 | 12·41 | | | | | | | |
| | 12·41 | 12·41 | 10·46 | 8·50 | 7·03 | 5·50 | 4·69 | 3·65 | ,, |
| ,, 19 | 12·41 | 12·41 | 12·41 | 7·85 | 5·92 | 3·97 | 2·54 | Nil | ,, |
| | 12·41 | 12·41 | 12·41 | 8·62 | 6·98 | 4·89 | 3·72 | 1·82 | ,, |
| ,, 20 | 12·41 | 12·41 | 12·41 | 9·06 | 6·70 | 4·37 | 2·72 | Nil | ,, |
| | 12·41 | 12·41 | 12·41 | 8·78 | 6·38 | 3·60 | 1·21 | ,, | ,, |
| ,, 21 | 12·41 | 12·41 | 12·41 | 9·85 | 7·29 | 4·60 | 2·82 | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 8·80 | 5·65 | 1·55 | Nil | ,, | ,, |
| ,, 22 | 12·41 | 12·41 | 12·41 | 10·05 | 7·35 | 4·51 | 2·75 | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 7·82 | 4·51 | Nil | Nil | ,, | ,, |
| ,, 23 | 12·41 | 12·41 | 12·41 | 10·00 | 7·25 | 4·79 | 3·47 | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 7·65 | 4·65 | Nil | Nil | ,, | ,, |

STATEMENT—*continued.*

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours | hours | hours | hours | hours | hours | hours | hours | hours |
| June 24 | 12·41 | 12·41 | 12·41 | 9·60 | 7·09 | 4·82 | 3·57 | 1·62 | Nil |
| | 12·41 | 12·41 | 12·41 | 7·35 | 4·28 | Nil | Nil | Nil | " |
| " 25 | 12·41 | 12·41 | 12·41 | 9·27 | 7·08 | 5·10 | 4·05 | 2·58 | " |
| | 12·41 | 12·41 | 12·41 | 7·58 | 4·75 | Nil | Nil | Nil | " |
| " 26 | 12·41 | 12·41 | 12·41 | 8·85 | 6·93 | 5·05 | 4·03 | 2·86 | " |
| | 12·41 | 12·41 | 12·41 | 7·45 | 4·81 | Nil | Nil | Nil | " |
| " 27 | 12·41 | 12·41 | 12·41 | 8·87 | 7·02 | 5·25 | 4·29 | 3·32 | " |
| | 12·41 | 12·41 | 12·41 | 7·32 | 5·05 | 0·40 | Nil | Nil | " |
| " 28 | 12·41 | 12·41 | 12·41 | 8·68 | 7·09 | 5·45 | 4·55 | 3·58 | " |
| | 12·41 | 12·41 | 12·41 | 7·15 | 5·15 | 1·25 | Nil | Nil | " |
| " 29 | 12·41 | 12·41 | 12·41 | 8·59 | 7·02 | 5·45 | 4·58 | 3·53 | " |
| | 12·41 | 12·41 | 12·41 | 7·11 | 5·00 | 2·50 | Nil | Nil | " |
| " 30 | .. | .. | 12·41 | 8·61 | 7·08 | 5·51 | 4·60 | 3·62 | " |
| | 12·41 | 12·41 | 12·41 | 6·97 | 5·02 | 2·41 | Nil | Nil | " |
| July 1 | 12·41 | 12·41 | 12·41 | 8·67 | 6·93 | 5·30 | No mark | 3·29 | " |
| | 12·41 | 12·41 | 9·35 | 6·93 | 5·09 | 2·40 | Nil | Nil | " |
| " 2 | 12·41 | 12·41 | 11·20 | 8·61 | 6·90 | 5·07 | 4·02 | 2·72 | " |
| | 12·41 | 12·41 | 12·41 | 7·02 | 5·00 | 2·19 | Nil | Nil | " |
| " 3 | 12·41 | 12·41 | 12·41 | 8·45 | 6·62 | 4·62 | 3·39 | 1·90 | " |
| | 12·41 | 12·41 | 12·41 | 7·48 | 5·38 | 2·58 | Nil | Nil | " |
| " 4 | 12·41 | 12·41 | 12·41 | 8·65 | 6·54 | 4·19 | 2·68 | " | " |
| | 12·41 | 12·41 | 12·41 | 7·52 | 5·65 | 2·80 | Nil | " | " |
| " 5 | 12·41 | 12·41 | 12·41 | 8·77 | 6·43 | 3·48 | 1·11 | " | " |
| | 12·41 | 12·41 | 12·41 | 9·05 | 6·20 | 3·25 | Nil | " | " |
| " 6 | 12·41 | 12·41 | 12·41 | 8·62 | 5·72 | 1·76 | " | " | " |
| | 12·41 | 12·41 | 12·41 | 9·15 | 6·54 | 3·78 | 1·85 | " | " |
| " 7 | 12·41 | 12·41 | 12·41 | 7·84 | 4·74 | Nil | Nil | " | " |
| | 12·41 | 12·41 | 12·41 | 9·08 | 6·84 | 4·65 | 3·30 | 0·90 | " |
| " 8 | 12·41 | 12·41 | 12·41 | 7·53 | 4·71 | Nil | Nil | Nil | .. |
| | 12·41 | 12·41 | 12·41 | 9·12 | 7·22 | 5·31 | 4·38 | 3·27 | Nil |

STATEMENT—*continued.*

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours | hours | hours | hours | hours | hours | hours | hours | hours |
| July 9 | 12·41 | 12·41 | 12·41 | 7·01 | 4·60 | Nil | Nil | Nil | Nil |
| | 12·41 | 12·41 | 12·41 | 8·89 | 7·12 | 5·62 | 4·85 | 3·92 | 1·49 |
| „ 10 | 12·41 | 12·41 | 9·05 | 6·82 | 4·70 | 0·83 | Nil | Nil | Nil |
| | 12·41 | 12·41 | .. | .. | .. | .. | 4·96 | 4·25 | 2·41 |
| „ 11 | 12·41 | 12·41 | 10·11 | 8·48 | 7·11 | 5·73 | Nil | Nil | Nil |
| | 12·41 | 12·41 | 8·44 | 6·38 | 4·62 | 1·30 | 5·00 | .. | .. |
| „ 12 | 12·41 | 12·41 | 9·58 | 8·08 | 6·92 | 5·63 | 0·97 | 4·37 | 2·75 |
| | 12·41 | 12·41 | 7·85 | 6·29 | 4·85 | 2·97 | .. | Nil | Nil |
| „ 13 | 12·41 | .. | 9·19 | 8·04 | 6·84 | 5·73 | 5·23 | 4·51 | 3·02 |
| | 12·41 | 9·91 | 9·85 | 6·36 | 5·08 | 3·70 | 2·05 | Nil | Nil |
| „ 14 | 12·41 | 11·18 | 9·10 | 7·89 | 6·82 | 5·78 | 5·19 | 4·63 | 3·20 |
| | .. | 9·74 | 7·85 | 6·69 | 5·39 | 3·89 | 2·87 | 0·94 | Nil |
| „ 15 | 12·41 | 10·97 | 9·00 | 7·80 | 6·75 | 5·63 | 5·11<br>3·12<br>4·85 | 4·43 | 2·80 |
| | 12·41 | 12·41 | 8·25 | 6·91 | 5·59 | 4·02 | 3·25 | 1·72 | Nil |
| „ 16 | 12·41 | 12·41 | 12·41 | 12·41 | 5·75 | 4·25 | 3·25 | 1·90 | „ |
| | 12·41 | 12·41 | 8·75 | 7·15 | 6·80 | 5·54 | 4·85 | No mark | „ |
| „ 17 | 12·41 | 12·41 | 12·41 | 7·90 | 6·60 | 5·3 | 4·11 | 3·10 | „ |
| | 12·41 | 12·41 | 9·20 | 7·50 | 5·90 | 4·12 | 3·02 | 8·78 | „ |
| „ 18 | 12·41 | 12·41 | 10·20 | 7·80 | 6·00 | 3·80 | 2·38 | Nil | „ |
| | 12·41 | 12·41 | 12·41 | 8·20 | 6·17 | 3·90 | 2·25 | „ | „ |
| „ 19 | 12·41 | 12·41 | 12·41 | 7·73 | 5·37 | 1·22 | Nil | „ | „ |
| | 12·41 | 12·41 | 12·41 | 9·12 | 7·00 | 4·30 | 1·32 | „ | „ |
| „ 20 | 12·41 | 12·41 | 12·41 | 8·30 | 4·77 | Nil | Nil | „ | „ |
| | 12·41 | 12·41 | 12·41 | 9·93 | 7·22 | 4·15 | „ | „ | „ |
| „ 21 | 12·41 | 12·41 | 12·41 | 8·03 | 3·35 | Nil | „ | „ | „ |
| | 12·41 | 12·41 | 12·41 | 11·00 | 7·55 | 4·47 | 2·12 | „ | „ |
| „ 22 | 12·41 | 12·41 | 12·41 | 7·45 | 3·18 | Nil | Nil | „ | „ |
| | 12·41 | 12·41 | 12·41 | 10·85 | 7·60 | 4·67 | 2·82 | „ | „ |

STATEMENT—*continued.*

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours | hours | hours | hours | hours | hours | hours | hours | hours |
| July 23 | 12·41 | 12·41 | 12·41 | 8·70 | 3·40 | Nil | Nil | Nil | Nil |
| | 12·41 | 12·41 | 12·41 | 10·65 | 7·30 | 4·85 | .. | „ | „ |
| „ 24 | 12·41 | 12·41 | 12·41 | 8·55 | 4·00 | Nil | 3·37 | „ | „ |
| | 12·41 | 12·41 | 12·41 | 9·83 | 7·12 | „ | Nil | „ | „ |
| „ 25 | 12·41 | 12·41 | 12·41 | .. | .. | 5·00 | 3·69 | 2·18 | „ |
| | 12·41 | 12·41 | 12·41 | 7·89 | 5·19 | Nil | Nil | Nil | „ |
| „ 26 | 12·41 | 12·41 | 12·41 | 9·09 | 7·15 | 5·21 | 4·19 | 2·89 | „ |
| | 12·41 | 12·41 | 12·41 | 7·62 | 5·15 | Nil | Nil | Nil | „ |
| „ 27 | 12·41 | 12·41 | 12·41 | 8·81 | 7·05 | 5·21 | 4·31 | 3·30 | „ |
| | 12·41 | 12·41 | 12·41 | 7·23 | 5·12 | 2·02 | Nil | Nil | „ |
| „ 28 | 12·41 | 12·41 | 9·55 | 8·61 | 6·97 | 5·40 | 4·55 | 3·84 | 0·85 |
| | 12·41 | 12·41 | .. | 7·15 | 5·27 | 2·90 | Nil | Nil | Nil |
| „ 29 | 12·41 | 12·41 | 10·31 | 8·35 | 6·91 | 5·42 | 4·63 | 3·69 | 0·32 |
| | 12·41 | 12·41 | 9·22 | 7·10 | 5·40 | 3·32 | 1·55 | Nil | Nil |
| „ 30 | .. | .. | 10·15 | 8·30 | 6·76 | 5·22 | 4·47 | 3·51 | 0·79 |
| | 12·41 | 12·41 | 9·08 | 7·12 | 5·52 | 3·55 | 2·10 | Nil | Nil |
| „ 31 | 12·41 | 12·41 | 10·25 | 8·32 | 6 72 | 5·19 | 4·22 | 3·25 | „ |
| | 12·41 | 12·41 | 9·38 | 7·29 | 5·70 | 3·85 | 2·70 | Nil | „ |
| August 1 | 12·41 | 12·41 | 10·30 | 8·35 | 6·65 | 4·95 | 4·06 | 2·80 | „ |
| | 12·41 | 12·41 | 9·80 | 7·30 | 5·93 | 4·23 | 2·78 | 0·61 | „ |
| „ 2 | 12·41 | 12·41 | 10·24 | 8·22 | 6·44 | 4·44 | 3·24 | 1·50 | „ |
| | 12·41 | 12·41 | 12·41 | 7·90 | 6·22 | 4·33 | 3·26 | 1·48 | „ |
| „ 3 | 12·41 | 12·41 | 12·41 | 8·04 | 6·06 | 3·34 | 1·32 | Nil | „ |
| | 12·41 | 12·41 | 12·41 | 8·20 | 6·40 | 4·42 | 3·15 | 0·72 | „ |
| „ 4 | 12·41 | 12·41 | 12·41 | 7·96 | 5·28 | 0·84 | Nil | Nil | „ |
| | 12·41 | 12·41 | 12·41 | 9·14 | 7·02 | 4·82 | 3·60 | 1·36 | „ |
| „ 5 | 12·41 | 12·41 | 12·41 | 8·08 | 4·68 | Nil | Nil | Nil | „ |
| | 12·41 | 12·41 | 12·41 | 9·84 | 7·51 | 5·18 | 3·25 | 1·92 | „ |
| „ 6 | 12·41 | 12·41 | 12·41 | 7·60 | 3·96 | Nil | Nil | Nil | „ |
| | 12·41 | 12·41 | 12·41 | 10·00 | 7·58 | 5·40 | 4·32 | 3·02 | „ |

STATEMENT—*continued.*

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours 12·41 | hours 12 41 | hours 12·41 | hours 7·56 | hours 4·21 | hours Nil | hours Nil | hours Nil | hours Nil |
| August 7 | 12·41 | 12·41 | 12·41 | 7·66 | 7·56 | 5·80 | 4·89 | ,, | ,, |
| ,, 8 | 12·41 | 12·41 | 12·41 | 7·12 | 4·79 | Nil | Nil | 3·90 | ,, |
| | 12·41 | 12·41 | | | | | | | |
| ,, 9 | 12·41 | 12·41 | 12·41 | 8·80 | 7·30 | 5·82 | 5·05 | 4·24 | 1·78 |
| | 12·41 | 12·41 | 9·04 | 6·84 | 5·10 | 2·87 | 0·72 | Nil | Nil |
| ,, 10 | 12·41 | 12·41 | 10·06 | 8·40 | 7·06 | 5·86 | 5·21 | 4·52 | 2·90 |
| | 12·41 | 12·41 | 8·50 | 7·00 | 5·56 | 3·96 | 2·94 | 0·94 | Nil |
| ,, 11 | 12·41 | 12·41 | 9·56 | 8·10 | 7·00 | 5·90 | 5·29 | 4·70 | 3·14 |
| | 12·41 | 12·41 | 8·26 | 6·86 | 5·55 | 4·20 | 3·35 | 2·18 | Nil |
| ,, 12 | 12·41 | 12·41 | 8·92 | 7·70 | 6·67 | 5·61 | 5·10 | 4·35 | 3·10 |
| | .. | .. | 8·43 | 7·05 | 5·90 | 4·60 | 3·87 | 3·05 | Nil |
| ,, 13 | 12·41 | 12·41 | 9·10 | 7·90 | 6·81 | 5·60 | 4·97 | 4·41 | 2·81 |
| | 12·41 | 12 41 | 8·60 | 7·30 | 6·09 | 4·80 | 4·07 | 3·25 | Nil |
| ,, 14 | 12·41 | 12·41 | 7·05 | 7·60 | 6·45 | 5·20 | 4·52 | 3·70 | 1·70 |
| | 12·41 | 12·41 | 8·86 | 7·50 | 6·20 | 4·77 | 3·78 | 3·05 | Nil |
| ,, 15 | 12·41 | 12·41 | 9·16 | 7·60 | 6·18 | 4·60 | 3·60 | 2·40 | ,, |
| | 12·41 | 12·41 | 9·65 | 7·98 | 6·50 | 4·87 | 3·72 | 2·55 | ,, |
| ,, 16 | 12·41 | 12·41 | 9·70 | 7·75 | 6·18 | 3·88 | 2·08 | Nil | ,, |
| | 12·41 | 12·41 | 12·41 | .. | .. | 5·05 | 3·75 | 1·80 | ,, |
| | .. | .. | .. | 8·72 | 6·98 | .. | Nil | Nil | ,, |
| ,, 17 | 12·41 | 12·41 | 12·41 | 8·24 | 5·82 | 1·98 | 2·23 | ,, | ,, |
| | 12 41 | 12·41 | 12·41 | 9·75 | 7·56 | 5·13 | Nil | ,, | ,, |
| ,, 18 | 12·41 | 12·41 | 12·41 | 8·25 | 4·89 | Nil | ,, | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 10·50 | 7·65 | 3·80 | ,, | ,, | ,, |
| ,, 19 | 12·41 | 12·41 | 12·41 | 9·00 | Nil | Nil | ,, | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 11·97 | 7·82 | 3·20 | ,, | ,, | ,, |
| ,, 20 | 12·41 | 12·41 | 12·41 | .. | Nil | Nil | ,, | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 12·41 | 7·85 | 3·35 | .. | ,, | ,, |
| ,, 21 | 12·41 | 12·41 | 12·41 | 12·41 | 3·12 | Nil | Nil | ,, | ,, |
| | 12·41 | 12·41 | 12·41 | 12·41 | 7·61 | 4·40 | ,, | ,, | ,, |

STATEMENT—*continued.*

| Date. | Levels. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 88 | 86 | 84 | 82 | 80 | 78 | 77 | 76 | 74 |
| 1889. | hours | hours | hours | hours | hours | hours | hours | hours | hours |
| Aug. 22 | 12·41 | 12·41 | 12·41 | 12·41 | 4·01 | Nil | 2·15 | Nil | Nil |
| | 12·41 | 12·41 | 12·41 | 12·41 | 6·88 | 4·41 | Nil | | |
| „ 23 | 12·41 | 12·41 | 12·41 | 12·41 | .. | .. | 2·88 | Nil | Nil |
| | 12·41 | 12·41 | 12·41 | 7·82 | 4·54 | Nil | Nil | „ | „ |
| „ 24 | 12·41 | 12·41 | 12·41 | 8·92 | 6·64 | 4·57 | 3·40 | 1·56 | „ |
| | 12·41 | 12·41 | 12·41 | 7·25 | 4·98 | 0·40 | Nil | Nil | „ |
| „ 25 | 12·41 | 12·41 | 9·75 | 8·38 | 6·65 | 4·87 | 3·87 | 2·83 | „ |
| | 12·41 | 12·41 | .. | 7·25 | 5·30 | 2·69 | Nil | Nil | „ |
| „ 26 | 12·41 | 12·41 | 10·35 | 8·28 | 6·70 | 5·10 | 4·21 | 3·15 | „ |
| | 12·41 | 12·41 | 9·08 | 7·10 | 5·44 | 3·59 | 2·45 | Nil | „ |
| „ 27 | 12·41 | 12·41 | 9·98 | 8·12 | 6·69 | 5·22 | 4·44 | 3·51 | 0·83 |
| | .. | .. | 8·92 | 7·18 | 5·70 | 4·13 | 3·20 | 2·04 | Nil |
| „ 28 | 12·41 | 12·41 | 9·49 | 7·85 | 6·48 | 5·12 | 4·38 | 3·50 | 1·12 |
| | 12·41 | 12·41 | 8·75 | 7·31 | 5·91 | 4·49 | 3·68 | 2·73 | Nil |
| „ 29 | 12·41 | 12·41 | 9·32 | 7·80 | 6·45 | 5·05 | 4·28 | 3·32 | „ |
| | 12·41 | 12·41 | 9·08 | 7·59 | 6·21 | 4·84 | 4·05 | 3·12 | „ |
| „ 30 | 12·41 | 12·41 | 9·38 | 7·78 | 6·39 | 4·89 | 4·06 | 2·93 | „ |
| | 12·41 | 12·41 | 9·45 | 7·84 | 6·55 | 5·05 | 4·31 | 3·35 | „ |
| „ 31 | 12·41 | 12·41 | 9·60 | 7·85 | 6·38 | 4·59 | 3·45 | 2·01 | „ |
| | 12·41 | 12·41 | 10·98 | 8·36 | 6·95 | 5·40 | 4·60 | 3·59 | „ |

STATEMENT SHOWING THE VARIOUS DRAINAGE AREAS OF BOMBAY.

| Area in Acres. | Description of Locality. |
|---|---|
| 110 | East side of Malabar Hill, drained into sea. |
| 294 | West „ „ „ „ |
| 337 | West side of Khambala Hill, drained into sea. |
| 251 | West side of Warli Hill „ „ |
| 2,308 | District drained by Warli Channel. |
| 525 | West portion of Mahim, drained into Mahim Bay. |
| 1,321 | District drained by Dharavi Channel. |
| 151 | North side of Dharavi Road, drained into Mahim River. |
| 185 | District drained by Sion Channel. |
| 3,029 | West side of Sewri and Sion Roads, drained into sea. |
| 668 | West side of Mazagon Road, drained into sea. |
| 200 | East side of Mazagon, eventually draining towards flats. |
| 784 | Additional area, draining into the storm-water reservoir. |
| 928 | Flats drained into open main drain channel. |
| 256 | Gowalia Tank and Khambala Hill, draining towards the open main drain channel. |
| 736 | District drained by Parel and Bellasis Road drain, and finally falling into old main drain. |
| 336 | Khetwadi district, finally draining into old main drain channel. |
| 103 | District drained by Charni Road drain. |
| 60 | „ „ Sonapore drain. |
| 52 | „ „ Marine Lines drain. |
| 163 | Esplanade, draining into sea. |
| 265 | Elphinstone Reclamation, drained by Carnac Bunder outfall. |
| 144 | Mody Bay district, drained into sea. |
| 79 | Frere Road, drained by Mandvi outfall. |
| 273 | Fort district, drained by Mint Road outfall. |
| 61 | Dock and Custom House portion of Fort, drained into sea. |
| 257 | Colaba (western district), drained into sea. |
| 208 | „ eastern „ „ „ |
| 147 | Portion west of Queen's Road, falling into sea. |
| 14,231 | |

STATEMENT showing Areas of the different Districts and total Areas drained by different Ovoid Sewers, and the Populations served by them, together with the Size of the Sewers and their Gradients.

| Ovoid Sewer. | District. | Acres. | Population (as per Census of 1881). | Total. | Discharging Capacity, 2/3rds full. Cube Feet per Minute. | Size of Sewer. ft. in. ft. in. |
|---|---|---|---|---|---|---|
| Mint Road to Shek Memn Street. | Esplanade | 214 | 4,429 | | | |
| | Fort South | 131 | 3,515 | | | |
| | Fort North | 133 | 33,828 | | | |
| | Total .. | 478 | | 40,772 | 707 | 2 6 × 3 9 |
| Carnac Road. | Umarkhari | 8 | 4,164 | | | |
| Sewer from Frere Road to Shek Memn Street. | Dongri .. | 285 | 33,290 | | | |
| | Esplanade | 201 | 4,159 | | | |
| | Mandvi .. | 164 | 42,351 | | | |
| | Chakla .. | 17 | 12,349 | | | |
| | Total .. | 675 | | 96,313 | 752 | 2 6 × 3 9 |
| Shek Memn Street to Kavasji Patel Tank. | Chackla .. | 19 | 13,802 | | | |
| | Market .. | 79 | 43,609 | | | |
| | Dhobi Taloo | 23 | 9,155 | | | |
| | Fanaswadi | 20 | 3,715 | | | |
| | Bhuleswar | 18 | 9,145 | | | |
| | Girgam .. | 12 | 2,450 | | | |
| | Esplanade | 18 | 373 | | | |
| | Mint Road Sewer .. | 478 | 41,772 | | | |
| | Carnac Road Sewer .. | 675 | 96,313 | | | |
| | Total .. | 1,342 | | 220,334 | 796 | 2 8 × 4 0 |
| Kavasji Patel Tank to Khetwadi 10th Lane. | Kombharwada .. | 19 | 14,452 | | | |
| | Khetwadi .. | 97 | 16,796 | | | |
| | Carried over | 116 | 31,248 | | | |

STATEMENT—*continued.*

| Ovoid Sewer. | District. | Acres. | Population (as per Census of 1881). | Total. | Discharging Capacity, 2/3rds full. Cube Feet per Minute. | Size of Sewer. ft. in. ft. in. |
|---|---|---|---|---|---|---|
| | Brought over | 116 | 31,248 | | | |
| | Girgam .. | 12 | 2,450 | | | |
| | Sewer from Shek Memn Street to Kavasji Patel Tank | 1,342 | 220,334 | | | |
| | Total .. | 1,470 | | 254,032 | 1,304 | 3 4×5 0 |
| Queen's Road .. | Dhobi Taloo | 76 | 30,254 | | | |
| | Fanaswadi | 105 | 19,503 | | | |
| | Market .. | 10 | 5,521 | | | |
| | Girgam .. | 100 | 20,419 | | | |
| | Khetwadi .. | 61 | 10,562 | | | |
| | Chopati .. | 103 | 10,184 | | | |
| | Walkeshwar | 10 | 210 | | | |
| | Esplanade | 137 | 2,835 | | | |
| | Total .. | 602 | | 99,488 | 704 | 2 6×3 9 |
| Khetwadi 10th Lane to Grant Road. | Khetwadi .. | 12 | 2,078 | | | |
| | Kavasji Patel Tank to Khetwadi 10th Lane .. | 1,470 | 254,032 | | | |
| | Queen's Road | 602 | 99,488 | | | |
| | Total .. | 2,084 | | 355,598 | | |
| Kamatipura .. | Tardeo .. | 13 | 1,156 | | | |
| | Kamatipura | 55 | 23,713 | | | |
| | Total .. | 68 | | 24,869 | 749 | 2 6×3 9 |

STATEMENT—*continued.*

| Ovoid Sewer. | District. | Acres. | Population (as per Census of 1881). | Total. | Discharging Capacity, 2/3rds full, Cube Feet per Minute. | Size of Sewer. |
|---|---|---|---|---|---|---|
| | | | | | | ft. in. ft. in. |
| Grant Road to Clerk Road. | Bhuleshwar | 57 | 28,961 | | | |
| | Chakla .. | 15 | 10,896 | | | |
| | Chopati .. | 8 | 791 | | | |
| | Milkeswar | 4 | 84 | | | |
| | Tardeo .. | 215 | 19,125 | | | |
| | Umarkhari | 97 | 50,492 | | | |
| | Mahalaxmi | 152 | 3,058 | | | |
| | Byculla .. | 4 | 111 | | | |
| | Khanbhawadi | 27 | 20,538 | | | |
| | Kamatipura | 11 | 4,742 | | | |
| | Khara Taloo | 41 | 28,691 | | | |
| | 1st Nagpada | 29 | 9,372 | | | |
| | 2nd Nagpada | 34 | 15,922 | | | |
| | Total .. | 724 | 192,783 | | 2,567 | 4 8×7 0 |
| Kamatipura .. | Kamatipura | 68 | 24,869 | | | |
| Khetwadi 10th Lane to Grant Road. | Khetwadi 10th Lane to Grant Road .. | 2,084 | 355,598 | | | |
| | Total .. | 2,876 | | 573,250 | | |
| Ripon Road.. .. | Byculla .. | 260 | .. | 7,186 | 740 | 2 6×3 9 |
| Clerk Road .. .. | Tarwadi .. | 318 | 9,654 | | | |
| | Byculla .. | 180 | 4,974 | | | |
| | Warli .. | 71 | 702 | | | |
| | Ripon Road | 260 | 7,186 | | | |
| | Total .. | 829 | | 22,516 | 740 | 2 6×3 9 |
| Clerk Road to Pumping-station. | Grant Road to Clerk Road .. | 2,876 | 573,250 | | | |
| | Clerk Road | 829 | 22,516 | | | |
| | Total .. | 3,705 | | 595,766 | 3,328 | 5 4×8 0 |

## MEMORANDUM BY SURGEON-MAJOR WEIR, MEDICAL OFFICER OF HEALTH.

The nuisance felt during the monsoon from the flats was more serious than for many years. The nuisance was caused by a deposit of sludge across the reservoir.

A. Interrupting the current of sewage.

B. Polluting the water.

I wrote two reports on the causes of the offensive smells. Before giving these reports, I may mention that the deposit in some of the sewers in the Fort, as in the Church Gate and Marine Street sewers, was exceptionally small. In the Marine Street sewer there was practically none.

Popularly the nuisance from the Flats was ascribed to sewer emanations, but the nuisance was not due to the sewers, nor to any nuisance caused within the sewers. It was due to the deposit in the reservoir and its effects.

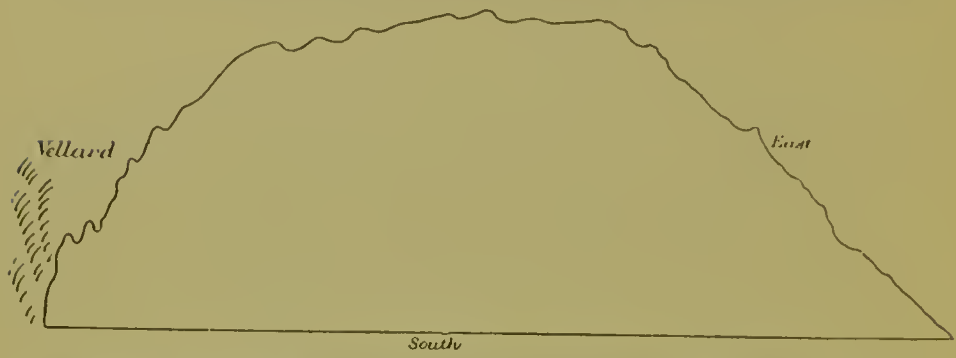
### Report Dated 18th October, 1889.

" I have the honour to submit the result of observations I made this morning. A little after six, one of the sluice gates at Clerk Road was opened, and I followed the sewage from the sluice gates to the Vellard, Mahalaxmi ; the stream of sewage on entering the reservoir set towards the Vellard, and was preceded by a wave or border of charcoal and sewage matters some two feet broad, having a wavy outline, as

The rate of motion was, on an average, 45 feet in one minute and twenty seconds as I timed it. I followed the sewage till the current arrived at the Vellard. It now extended in an irregular line from the Vellard east, across the reservoir, having the greatest surface north as follows, the apex being towards the Vellard.

" In about two hours, the surface of the water of the reservoir, as far as I could see, was covered with sewage, i. e., in a few words the reservoir was more or less converted into a sewage pond. The set towards the

Vellard explains the offensive smell which you have observed on Khambala Hill. With a set towards the Vellard, the roads on either side of the




Khambala Hill act as funnels, and attract the foul vapours towards the hill. The Acting Executive Engineer, Mr. Smith, attributes the set of the sewage to the deposit on the east of the reservoir. The removal of this deposit has been under your consideration."

*Report dated 6th November*, 1889.

"The liquid sewage in the open main drain gave 20 parts per million of free ammoniacal products, and the water from the south-east side of the reservoir, 14; while the water from near the outlet near Love Grove yielded 17. These have been the results of my examinations. The quality of the water in the open drains on the Flats varies very much; those communicating during the rains with the open drain or with the drainage of dwellings are sewage tainted.

"I may offer an opinion on the nuisance from the reservoir during this year, and the cause of the nuisance being more observed than in the last year. In my opinion the cause is due to the deposit in the reservoir.

"The deposit—

"A.—Obstructs the circulation of the water.

"B.—Retards the diffusion of the sewage.

"C.—Causes a current of sewage to the Vellard.

"D.—Exposes a greater surface of sewage to the atmosphere.

"E.—And, therefore, brings the sewage the distance between the east of the reservoir and Mahalaxmi, so much nearer to Khambala and Malabar Hills.

"I forward in a bottle of sewage a sample of the odours which have been observed from the direction of the Flats."

It must be recollected that the new sewer system is tried as no other

system in the world is tried. There is discharging daily in fæcal mass some 340 (three hundred and forty) tons of night-soil into the sewers. And why is this done? Because the harbour outfall, the ancient way of discharge, was closed by Government, and because the interests of the city have been sacrificed to the interests of the harbour. Both Mr. Walton and I objected strongly to the discharge of night-soil in mass from the Carnac Bunder night-soil depot into the sewers.

The following is one of my reports:—

"I believe the discharge of the night-soil brought to the Carnac Bunder Night-soil Depot into the new sewer in the Esplanade Cross Road within a limited period of about six hours would be attended with danger. I am further doubtful whether any practicable system of flushing would prevent portions of the mass of night-soil that would be poured into the sewer adhering to the sewer and blocking the sewer subsequently. Night-soil is most tenacious. The circulation for some hours through the city of an immense current of night-soil is attended undoubtedly with danger; although the danger is less in proportion to the freshness of the organic fluids and particles. The danger is very much greater than the danger that would attend the admission of the same quantity in divided portions and at divided points.

"I do not think the emptying of night-soil into the drains at junction of drains and sweepers' gullies is practicable; it would create a most serious nuisance, a nuisance that would be protested against. I believe it is impracticable."

Memorandum of Temperature of Sewage in Main Sewers on 1st February, 1890. Taken by Mr. Baldwin Latham.

| Locality. | Temperature. | Time. | Remarks. |
|---|---|---|---|
| | | A.M. | |
| Temperature in shade at Pumping Station, Love Grove .. | 69·3 | 7.30 | In shade. |
| Shred-lifter chamber .. .. | 75·7 | 7.30 | Sewage. |
| " " " .. .. | 75·7 | 7.35 | " |
| From pumping-station .. .. | 75·5 | 7.50 | Manhole No. 5. |
| " " " .. .. | 74·9 | 8.10 | " No. 2. |
| In Clerk Road manhole .. .. | 75·2 | 8.15 | |
| " " " .. .. | 74·2 | 8.15 | On ovoid sewer, east manhole No. 1. |
| North side of the Bellasis Bridge .. .. .. .. .. | 75·4 | 8.45 | At pipe depot manhole. |
| Air Temperature .. .. | 74·6 | 8.45 | In shade. |
| In Gilder Street main sewer .. | 76·5 | 9.10 | |
| " " old sewer .. | 73·5 | 9.10 | On old manhole. |
| Bapty Road main sewer .. .. | 76·3 | 9.20 | On storm water manhole. |
| " old sewer .. .. | 73·7 | 9.20 | |
| Falkland Road .. .. .. | 76·2 | 9.30 | Manhole No. 1. |
| 10th Khetwadi Lane, north side | 76·2 | 9.40 | In manhole. |
| " " " south side | 76·0 | 9.45 | " " |
| Khetwadi Back Road .. .. | 74·8 | 9.45 | On Queen's Road sewer. |
| Khetwadi Back Road, opposite the 9th lane .. .. .. | 77·0 | 9.45 | On main sewer. |
| Khetwadi Back Road .. .. | 73·8 | 9.50 | Fresh water from main pipe. |
| Air Temperature .. .. | 75·7 | 9.50 | In shade. |
| 15th Khetwadi Lane .. .. | 73·5 | 10.04 | Fresh water from main pipe. |

NOTES taken on 3rd February, 1890. (Temperature taken by Mr. Baldwin Latham.)

| Locality. | Temperature. | Time. | Remarks. |
|---|---|---|---|
| At Pumping Station, Love Grove .. .. | 75·7 | A.M. 7.45 | Sewage, shred-lifter chamber. |
| Air Temperature .. .. .. | 69·4 | 7.45 | In shade. |
| Water for Condensers .. | 89·6 | 7.55 | In cooling tank. |
| Water from Condensers | 105·3 | 7.55 | In channel between tank and engine house. |
| " " " | 107·2 | .. | " " " |
| " " " | 109·6 | | |
| " " " | 106·7 | | |

MEMORANDUM OF STATE OF SEWERS in Bombay, taken under Executive Engineer's instructions.

| Location. | Depth of Sewage. | | Depth of Silt. | | Total Depth of Sewage and Silt. | | Remarks. |
|---|---|---|---|---|---|---|---|
| *Hornby Road and Town Hall Sewer, January* 17, 1890. | ft. | in. | ft. | in. | ft. | in. | |
| North Corner School of Art .. | 1 | 1 | 0 | 7½ | 1 | 8½ | |
| Manhole .. .. .. .. .. | 1 | 0 | 0 | 9½ | 1 | 9½ | |
| Manhole .. .. .. .. .. | 1 | 0 | 0 | 8 | 1 | 8 | |
| North end of Victoria Terminus | 0 | 9½ | 0 | 8 | 1 | 5½ | |
| North of Novelty Theatre .. | 0 | 9 | 0 | 8½ | 1 | 5½ | |
| Entrances to platform, Victoria Terminus .. .. .. .. | 0 | 9 | 0 | 6 | 1 | 3 | |
| Dome of Victoria Terminus .. | 0 | 11½ | 0 | 4½ | 1 | 4 | |
| Opposite Post Office door, but little to east .. .. .. | 0 | 9½ | 0 | 7 | 1 | 4½ | |
| Tanks for road watering, European General Hospital .. | 0 | 9 | 0 | 6 | 1 | 3 | |
| Goa Street .. .. .. .. | 0 | 8 | 1 | 1½ | 1 | 9½ | |
| North of corner Mint Road and Frere Road .. .. .. | 0 | 7 | 1 | 0½ | 1 | 7½ | |
| Agiari Street .. .. .. .. | 0 | 11½ | 0 | 10½ | 1 | 10 | |

MEMORANDUM OF STATE OF SEWERS—*continued.*

| Location. | Depth of Sewage. | | Depth of Silt. | | Total Depth of Sewage and Silt. | | Remarks. |
|---|---|---|---|---|---|---|---|
| *Hornby Road, &c.—continued.* | ft. | in. | ft. | in. | ft. | in. | |
| Ballard Road .. .. .. .. | 0 | 5 | 1 | 4 | 1 | 9 | |
| Mint, north circle manhole .. | 0 | 6 | 1 | 3½ | 1 | 9½ | |
| 18-in. pipe manhole .. .. | 1 | 1½ | 0 | 6½ | 1 | 8 | |
| Penstock manhole on old drain | .. | | 1 | 9 | | | |
| *Queen's Road Sewer, January* 18, 1890. | | | | | | | |
| Khetwadi, 10th Lane .. .. | 2 | 7 | 1 | 10 | 4 | 5 | |
| „ 11th Lane .. .. | 2 | 2 | 2 | 2 | 4 | 4 | |
| „ 13th Lane .. .. | 2 | 5 | 1 | 11 | 4 | 4 | |
| Charni Road, corner .. .. | 2 | 7 | 1 | 10 | 4 | 5 | |
| Khetwadi, main road .. .. | 3 | 9½ | 0 | 7 | 4 | 4½ | |
| Naserwanji Parakh's house .. | 2 | 4½ | 1 | 9 | 4 | 1½ | |
| Girgam Back Road .. .. | 3 | 3½ | 1 | 1 | 4 | 4½ | |
| North of Eye Hospital .. .. | 2 | 5 | 1 | 11 | 4 | 4 | |
| Girgam Road .. .. .. .. | 3 | 1 | 1 | 4 | 4 | 5 | |
| North of mill .. .. .. .. | 2 | 10 | 1 | 6 | 4 | 4 | |
| Charni Road and Queen's Road | 2 | 8 | 2 | 0 | 4 | 8 | |
| Centre of Bhoras Sanatorium | 3 | 3½ | 1 | 2½ | 4 | 6 | |
| Thakodwar Road .. .. .. | 3 | 8 | 1 | 9 | 5 | 5 | |
| Mahomedan Burial Ground .. | 4 | 3½ | 1 | 6½ | 5 | 10 | |
| Chandanwadi Latrine .. .. | 3 | 2 | 1 | 10 | 5 | 0 | |
| Next N. of Marine L. Road .. | 4 | 1½ | 0 | 2½ | 4 | 4 | |
| Corner Wellington Street .. | 4 | 0 | Nil. | | 4 | 0 | |
| Hospital Lane.. .. .. .. | 3 | 0 | „ | | 3 | 0 | |
| Dr. Crimmin's bungalow (Capt. Parker) .. .. .. .. | 2 | 4 | „ | | 2 | 4 | |
| Side road (southernmost) .. | 1 | 1 | „ | | 1 | 1 | |
| W. F. Melvin .. .. .. .. | .. | | .. | | 0 | 4 | |
| Church Gate Street (195 feet) | .. | | .. | | 0 | 1¼ | |

MEMORANDUM OF STATE OF SEWERS—*continued.*

| Location. | Depth of Sewage. | | Depth of Silt. | | Total Depth of Sewage and Silt. | | Remarks. |
|---|---|---|---|---|---|---|---|
| *Clerk Road Sewer, January* 20, 1890. | ft. | in. | ft. | in. | ft. | in. | |
| Head manhole .. .. .. | 1 | 1 | 0 | 9 | 1 | 10 | |
| 2nd from manhole west .. | 0 | 3½ | 1 | 1½ | 1 | 5 | |
| De Lisle Road .. .. .. | 1 | 2 | 0 | 5 | 1 | 7 | |
| Centre of Hay Stack's Ground | 0 | 4 | 1 | 2 | 1 | 6 | |
| New Culvert .. .. .. .. | 0 | 7 | 1 | 1 | 1 | 8 | |
| Arthur Road, 9-inch pipe .. | 0 | 4 | 1 | 10 | 2 | 2 | |
| Level crossings B. B. & C. I. Ry. | 1 | 1 | 1 | 8 | 2 | 9 | |
| Opposite Grand Stand .. .. | 1 | 10 | 1 | 9 | 3 | 7 | |
| Last on Clerk Road sewer .. | 3 | 0 | 1 | 10 | 4 | 10 | |
| *Main Sewer, January* 20, 1890. | | | | | | | |
| Clerk Road Bridge .. .. .. | 3 | 3 | 3 | 3 | 6 | 6 | |
| 1st north of bell-mouth junction .. .. .. .. .. | 3 | 0 | 4 | 3 | 7 | 3 | |
| South bund running east .. | 3 | 3 | 4 | 1 | 7 | 4 | |
| 3rd manhole north of ditto .. | 3 | 6 | 3 | 6 | 7 | 0 | |
| 6th ,, ,, .. | 3 | 6 | 3 | 11 | 7 | 5 | |
| Next manhole south of middle bund running east .. .. | 4 | 2 | 3 | 3 | 7 | 5 | |
| Next manhole north of preceding .. .. .. .. .. | 7 | 9 | 0 | 9 | 8 | 6 | |
| ,, ,, ,, | 6 | 8 | 1 | 8 | 8 | 4 | |
| Intermediate .. .. .. .. | 7 | 0 | 1 | 6 | 8 | 6 | |
| 1st manhole south of north bund running east .. .. | 7 | 4 | 0 | 9 | 8 | 1 | |
| 3rd manhole from shred-lifter sump .. .. .. .. .. | 5 | 2 | 2 | 11 | 8 | 1 | |
| 2nd ,, ,, ,, | 5 | 0 | 3 | 1 | 8 | 1 | |
| 1st ,, ,, ,, | 7 | 4 | 0 | 8 | 8 | 0 | |
| Shred-lifter sump, sunk 12 in. | 8 | 8 | Nil. | | 8 | 8 | |

Memorandum of State of Sewers—*continued.*

| Location. | Depth of Sewage. | | Depth of Silt. | | Total Depth of Sewage and Silt. | | Remarks. |
|---|---|---|---|---|---|---|---|
| *Ripon Road Sewer, January* 20, 1890. | ft. | in. | ft. | in. | ft. | in. | |
| Head manhole.. .. .. .. .. | 0 | 8 | 0 | 7 | 1 | 3 | |
| 2nd ,, .. .. .. .. .. | 0 | 9½ | 0 | 8½ | 1 | 6 | |
| 4th ,, .. .. .. .. .. | 1 | 3 | 0 | 4 | 1 | 7 | |
| 6th ,, .. .. .. .. .. | 1 | 7 | 0 | 5 | 2 | 0 | |
| 8th ,, .. .. .. .. .. | 1 | 4 | 1 | 0 | 2 | 4 | |
| 10th ,, .. .. .. .. .. | 1 | 6 | 1 | 0 | 2 | 6 | |
| Sankli Street .. .. .. .. | 1 | 1 | 1 | 4 | 2 | 5 | |
| 2nd manhole north.. .. .. | 1 | 3½ | 0 | 9½ | 2 | 1 | |
| 4th ,, ,, .. .. | 1 | 6½ | 0 | 7½ | 2 | 2 | |
| Agripada open drain .. .. | 1 | 0 | 0 | 9 | 1 | 9 | |
| ,, connection manhole | 1 | 4 | 0 | 8 | 2 | 0 | |
| Indian Manufacturing Company's Mill .. .. .. | 0 | 4 | 1 | 3 | 1 | 7 | |
| Ripon Mill (centre) .. .. | 0 | 3½ | 1 | 4½ | 1 | 8 | |
| South part of Hindustan Mill | 0 | 5½ | 1 | 4½ | 1 | 10 | |
| 2nd manhole from Jacob's Circle .. .. .. .. .. | 0 | 6 | 1 | 5 | 1 | 11 | |
| Clerk Road sewer (west aisle of fountain).. .. .. .. | 1 | 8½ | 0 | 7½ | 2 | 4 | |

Memorandum of Depths of Sewage taken on the Morning of the 24th January, 1890, under Executive Engineer's instructions.

| Locality. | Depth of Silt. | Depth of Sewage above Silt. | Total Depth of Silt and Sewage. | Remarks. |
| --- | --- | --- | --- | --- |
| | | | ft. in. | |
| Kamatipura Centre Street (old brick sewer), opposite 12th Kamatipura Street .. .. .. .. | Not taken separately. | Very little. | 1 6 | |
| Kamatipura Centre Street (old brick sewer), opposite 10th Kamatipura Street .. .. .. .. | " | " | 1 6 | |
| | ft. in. | ft. in. | | |
| Kursetji Sukhlaji Street, at 7th Kamatipura Street | 0 4½ | 0 7 | 0 11½ | |
| Bapty Road (next manhole west of Kursetji Street) (storm-water drain) .. | 0 5 | 0 8 | 1 1 | |
| Bapty Road (ovoid sewer), at Kamatipura Centre Road .. .. .. .. | 2 0 | 0 5 | 2 5 | |
| Bapty Road (ovoid sewer), at Trimback Parashram Street .. .. .. .. | 2 7 | 0 3 | 2 10 | |
| Bapty Road (ovoid sewer), at Kamatipura Bazaar Street .. .. .. .. | 2 2 | 0 9 | 2 11 | |
| Bapty Road (storm-water drain), at Kamatipura Bazaar Road .. .. | 1 8 | 1 4 | 3 0 | |
| Bapty Road (old main drain), at Stable Street | 0 11 | 0 7 | 1 6 | |
| Kursetji Suklaji Street (south end, near latrines) | 0 10 | 1 2 | 2 0 | |
| Grant Road (manhole between Suklaji Street and Falkland Road) .. .. | 1 9 | 1 7 | 3 4 | |
| New main ovoid sewer at junction of Falkland Road and 10 Khetwadi Road .. .. .. .. | 2 1 | 4 1 | 6 2 | Mr. Baker's men were removing silt at the time of these observations at these places. |
| Next manhole on Falkland Road .. .. .. .. | 3 5 | 2 10 | 6 3 | |
| Manhole on Falkland Road, near Bapty Mills | 3 3 | 3 1 | 6 4 | |
| Falkland Road, at junction of Bapty Road .. .. | 0 1 | 6 1 | 6 2 | |

Peshutan H. Dustoor.

Memorandum of Depths of Sewage, taken on the morning of the 27th January, 1890, under Executive Engineer's instructions.

| Locality. | Depth of Silt. | Depth of Sewage above Silt. | Total Depth of Silt and Sewage. | Remarks. |
|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | |
| Manhole on Frere Road at the north gate of Prince's Docks | 1 4 | 0 4 | 1 8 | |
| Manhole on main sewer at the east foot of Carnac Bridge.. | 0 7 | 1 0 | 1 7 | |

Peshutan H. Dustoor.

Observation in Sewer between Clerk Road and Love Grove, February 18, 1890, 4 p.m.

| Location. | Depth of Sewage. | Depth of Silt. | Total Depth of Sewage and Silt. | Remarks. |
|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | |
| Between Clerk Road and Love Grove .. .. .. .. .. | 2 3 | 3 8 | 5 11 | |
| " " " | 0 11 | 5 3 | 6 2 | |

SEWAGE PUMPING ENGINES AT LOVE GROVE.—COUNTER READINGS.

| Date. | Engine No. 1. | | Engine No. 2. | | Engine No. 3. | | Engine No. 4. | | Total Strokes. |
|---|---|---|---|---|---|---|---|---|---|
| | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | |
| 1889. May 18 | 651952 | .. | 637838 | .. | .. | .. | 674126 | | |
| „ 19 | 681321 | 29369 | 684533 | 46695 | .. | .. | 685445 | 11319 | 87383 |
| „ 20 | 694180 | 12859 | 706352 | 21819 | .. | .. | 712095 | 26650 | 61328 |
| „ 21 | 725968 | 31788 | 730000 | 23646 | .. | .. | 726652 | 14557 | 69993 |
| „ 22 | 753832 | 27864 | 750012 | 20012 | .. | .. | 740821 | 14169 | 62045 |
| „ 23 | 768336 | 14504 | 772105 | 22093 | .. | .. | 761968 | 21147 | 57744 |
| „ 24 | 790703 | 22367 | 790008 | 17903 | .. | .. | 784186 | 22218 | 62488 |
| „ 25 | 790704 | 000001 | 820057 | 30049 | .. | .. | 748416 | | |
| „ 26 | 816845 | 26141 | 850000 | 29943 | .. | .. | 807218 | 58802 | 114886 |
| „ 27 | 843936 | 27091 | 871390 | 21390 | .. | .. | 827529 | 20311 | 68792 |
| „ 28 | 853863 | 9927 | 907063 | 35673 | .. | .. | 845668 | 18139 | 63739 |
| „ 29 | 876498 | 22635 | 918978 | 11915 | .. | .. | 881751 | 36083 | 70633 |
| „ 30 | 902763 | 26265 | 947867 | 28889 | .. | .. | 893240 | 11489 | 66643 |
| „ 31 | 910665 | 7902 | 970909 | 23042 | .. | .. | 915368 | 22128 | 53072 |
| June 1 | 934182 | 23517 | 436 | 29527 | .. | .. | 918345 | 2977 | 56021 |
| „ 2 | 953397 | 19215 | 25356 | 24920 | .. | .. | 941246 | 22901 | 67136 |
| „ 3 | 975198 | 21801 | 36958 | 11602 | .. | .. | 968719 | 27473 | 60876 |
| „ 4 | 000248 | 25050 | 69855 | 32897 | .. | .. | 968720 | 1 | 57948 |
| „ 5 | 005478 | 5170 | 100050 | 30195 | .. | .. | 969723 | 1003 | 36368 |
| „ 6 | 070020 | 64542 | 125958 | 25908 | .. | .. | 996515 | 26792 | 117242 |
| „ 7 | 100120 | 30100 | 141010 | 15052 | .. | .. | 22352 | 25837 | 70989 |
| „ 8 | 116515 | 16395 | 172092 | 31082 | .. | .. | 56567 | 34215 | 81692 |
| „ 9 | 146168 | 29653 | 193370 | 21278 | .. | .. | 81025 | 24458 | 75389 |
| „ 10 | 161911 | 15743 | 225522 | 32152 | .. | .. | 106586 | 25561 | 73456 |
| „ 11 | 199021 | 37110 | 243492 | 17970 | .. | .. | 138445 | 31859 | 86939 |
| „ 12 | 223586 | 24565 | 274039 | 30547 | .. | .. | 139493 | 1048 | 56160 |
| „ 13 | 238781 | 15195 | 302422 | 28383 | .. | .. | 164782 | 25289 | 68867 |
| „ 14 | 272424 | 33643 | 321926 | 19504 | .. | .. | 192960 | 28178 | 81325 |
| „ 15 | 301305 | 28881 | 355740 | 33814 | .. | .. | 214606 | 21646 | 84341 |
| „ 16 | 338350 | 37045 | 389286 | 33466 | .. | .. | 215140 | 0534 | 71045 |
| „ 17 | 366056 | 27706 | 418606 | 29320 | .. | .. | 232879 | 17739 | 74765 |

Counter Readings—*continued.*

| Date. | Engine No. 1. | | Engine No. 2. | | Engine No. 3. | | Engine No. 4. | | Total Strokes. |
|---|---|---|---|---|---|---|---|---|---|
| | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | |
| 1889. June 18 | 399845 | 33189 | 430623 | 12017 | .. | .. | 270142 | 37263 | 82469 |
| „ 19 | 420880 | 39035 | 448037 | 17414 | .. | .. | 302420 | 32278 | 88727 |
| „ 20 | 450840 | 29960 | 476239 | 28206 | .. | .. | 307569 | 5149 | 63315 |
| „ 21 | 450841 | 00001 | 501968 | 25729 | .. | .. | 344933 | 37364 | 63094 |
| „ 22 | 475960 | 25119 | 515808 | 13840 | .. | .. | 374940 | 30007 | 68966 |
| „ 23 | 508469 | 32509 | 549115 | 33307 | .. | .. | 374932 | | |
| „ 24 | 544958 | 36489 | 563298 | 14183 | .. | .. | 398042 | 23110 | 73782 |
| „ 25 | 564526 | 19568 | 573700 | 10402 | .. | .. | 423390 | 25348 | 55318 |
| „ 26 | 574642 | 10116 | 583700 | 10000 | .. | .. | 454838 | 31448 | 51564 |
| „ 27 | 593675 | 19033 | 585764 | 2064 | .. | .. | 458742 | 3904 | 25001 |
| „ 28 | 621230 | 27555 | 586290 | 526 | .. | .. | 460588 | 1846 | 29927 |
| „ 29 | 656884 | 35654 | 615788 | 29498 | .. | .. | 470590 | 10002 | 75154 |
| „ 30 | 658133 | 01249 | 634220 | 18432 | .. | .. | 475580 | 4990 | 24671 |
| July 1 | .. | .. | 668350 | 34130 | .. | .. | 511320 | 35740 | 69870 |
| „ 2 | .. | .. | 685064 | 16714 | 828230 | .. | 542152 | 30832 | |
| „ 3 | 681670 | 23537 | .. | .. | 852520 | 24290 | 551627 | 9475 | 57302 |
| „ 4 | 714680 | 33010 | 710023 | 24959 | 863713 | 9193 | 553164 | 1537 | 67999 |
| „ 5 | 733547 | 18867 | 738488 | 28465 | .. | .. | 570124 | 16960 | 64292 |
| „ 6 | 736802 | 3255 | 760623 | 22135 | .. | .. | 589963 | 19839 | 45229 |
| „ 7 | 765215 | 28413 | 787701 | 17078 | .. | .. | .. | .. | 45491 |
| „ 8 | 791721 | 26506 | 817954 | 30253 | .. | .. | .. | .. | 56759 |
| „ 9 | 805121 | 13400 | .. | .. | .. | .. | 620442 | 30479 | 43879 |
| „ 10 | 812024 | 6903 | .. | .. | 885690 | 21977 | 621682 | 1240 | 30120 |
| „ 11 | 813104 | 1080 | 842508 | 24554 | 900456 | 14766 | 622404 | 722 | 41122 |
| „ 12 | .. | .. | 851828 | 9320 | 925110 | 24654 | 660038 | 37634 | 71608 |
| „ 13 | .. | .. | 875212 | 23384 | 950568 | 25458 | 670704 | 10666 | 59508 |
| „ 14 | 826496 | 13392 | .. | .. | 982415 | 31847 | 662211 | | |
| „ 15 | 831626 | 5130 | 901491 | 26279 | 1379 | 18964 | 702316 | 40095 | 90468 |
| „ 16 | 885946 | 54320 | 922701 | 21210 | .. | .. | 718491 | 16175 | 91705 |
| „ 17 | 885346 | .. | 951457 | 28756 | .. | .. | .. | | |
| „ 18 | 909940 | 24594 | 958165 | 6708 | .. | .. | 746232 | 27741 | 59043 |

COUNTER READINGS—*continued.*

| Date. | Engine No. 1. | | Engine No. 2. | | Engine No. 3. | | Engine No. 4. | | Total Strokes. |
|---|---|---|---|---|---|---|---|---|---|
| | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | |
| 1889. July 19 | 925762 | 15822 | 967698 | 9533 | .. | .. | 769544 | 23312 | 48667 |
| „ 20 | 947872 | 22110 | 998843 | 31145 | .. | .. | .. | .. | 53255 |
| „ 21 | 969845 | 21973 | 031468 | 32625 | .. | .. | .. | .. | 54598 |
| „ 22 | 992909 | 23064 | 059248 | 27780 | .. | .. | 774046 | 4502 | 55346 |
| „ 23 | 18604 | 25695 | 61174 | 1926 | .. | .. | 806365 | 32319 | 59940 |
| „ 24 | 43013 | 24409 | 88715 | 7541 | .. | .. | 830734 | 24369 | 56319 |
| „ 25 | 68007 | 24994 | 122015 | 33300 | .. | .. | 851496 | 20762 | 79056 |
| „ 26 | .. | .. | 157807 | 35792 | .. | .. | 880785 | 29289 | 65081 |
| „ 27 | 75577 | 7570 | 194045 | 36238 | .. | .. | 909280 | 28495 | 72303 |
| „ 28 | 111572 | 35995 | 202572 | 8527 | .. | .. | 937710 | 28430 | 72952 |
| „ 29 | 150025 | 38453 | 210923 | 8351 | .. | .. | 966026 | 28316 | 75120 |
| „ 30 | 185085 | 35060 | 242650 | 31727 | .. | .. | .. | .. | 66787 |
| „ 31 | 221068 | 35983 | 275022 | 32372 | .. | .. | .. | .. | 68355 |
| Aug. 1 | 231308 | 10240 | 306615 | 31593 | .. | .. | 993705 | 27679 | 69512 |
| „ 2 | .. | .. | 333182 | 26567 | 10210 | 8831 | 28230 | 28525 | 63923 |
| „ 3 | .. | .. | 353700 | 20518 | 40740 | 30530 | 52622 | 24392 | 75440 |
| „ 4 | .. | .. | 369704 | 16004 | 69978 | 29238 | 87178 | 34556 | 79798 |
| „ 5 | 248363 | 17055 | .. | .. | 97984 | 28006 | 122267 | 35089 | 80150 |
| „ 6 | 258846 | 10483 | 387905 | 18201 | 124855 | 26871 | 141544 | 19277 | 74832 |
| „ 7 | 293515 | 34669 | 416103 | 28198 | 150440 | 25585 | .. | .. | 88425 |
| „ 8 | 327890 | 34375 | 450415 | 34312 | .. | .. | 161382 | 19838 | 88525 |
| „ 9 | 355730 | 27840 | 472906 | 22491 | .. | .. | 182254 | 20872 | 71203 |
| „ 10 | 390680 | 34950 | .. | .. | .. | .. | 212830 | 30576 | 65526 |
| „ 11 | 424480 | 33800 | 501030 | 28124 | .. | .. | 218055 | 5225 | 67149 |
| „ 12 | 454081 | 29601 | 530935 | 29905 | .. | .. | 224118 | 6063 | 65569 |
| „ 13 | 477031 | 23050 | 564002 | 33067 | .. | .. | 229430 | 5312 | 61429 |
| „ 14 | 500071 | 23040 | 599432 | 35430 | .. | .. | .. | .. | 58470 |
| „ 15 | 503327 | 3256 | 635155 | 35723 | .. | .. | 253713 | 24283 | 63262 |
| „ 16 | 531223 | 27896 | 671360 | 36205 | .. | .. | .. | .. | 64101 |
| „ 17 | 566630 | 35407 | 686157 | 14797 | .. | .. | 276880 | 23167 | 50204 |
| „ 18 | 602374 | 35744 | 721179 | 35022 | .. | .. | 286950 | 10070 | 80836 |

COUNTER READINGS—*continued.*

| Date. | Engine No. 1. | | Engine No. 2. | | Engine No. 3. | | Engine No. 4. | | Total Strokes. |
|---|---|---|---|---|---|---|---|---|---|
| | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | Counters. | Strokes. | |
| 1889. | | | | | | | | | |
| Aug. 19 | 636038 | 25664 | 738138 | 16959 | .. | .. | 309032 | 22122 | 64745 |
| ,, 20 | 665168 | 29130 | 768208 | 30070 | 166122 | 15682 | 321653 | 12621 | 87503 |
| ,, 21 | 701485 | 36317 | 802961 | 34753 | 183254 | 17132 | .. | .. | 88202 |
| ,, 22 | 729955 | 28470 | 803550 | 0589 | 204855 | 21601 | 330368 | 8715 | 59375 |
| ,, 23 | 749708 | 19753 | 858848 | 55298 | 221554 | 16699 | 355362 | 24994 | 116744 |
| ,, 24 | 778283 | 28575 | 886142 | 27294 | 231050 | 9496 | 365176 | 9814 | 75179 |
| ,, 25 | 795314 | 17031 | 892638 | 6496 | 262658 | 31608 | 382711 | 17535 | 72670 |
| ,, 26 | 814820 | 19506 | 917741 | 25103 | 277982 | 15324 | 393428 | 10717 | 70650 |
| ,, 27 | 836188 | 21368 | 952365 | 34624 | .. | .. | 415878 | 22450 | 78442 |
| ,, 28 | 864620 | 28432 | 984077 | 31712 | .. | .. | 447070 | 31192 | 91336 |
| ,, 29 | 878750 | 14130 | 015573 | 31496 | .. | .. | 479893 | 32823 | 78449 |
| ,, 30 | 905450 | 26700 | 50818 | 35245 | .. | .. | 505920 | 26027 | 87972 |
| ,, 31 | 933085 | 27635 | 87038 | 36220 | .. | .. | 526610 | 20690 | 84545 |

NOTE.—A glance at the total number of strokes made daily by all the engines, or by each individual engine, shows some remarkable discrepancies which, if correct, point to enormous variations in the volume of sewage. On some days, as for instance, on the 30th June, the average number of strokes per minute made by all the engines was 17·13, while on the 6th of the same month the average number of strokes per minute was 81·42, or the volume of sewage pumped in one day exceeded the other by $4\frac{3}{4}$ times its volume.

The return also shows that occasionally one engine raises an improbable quantity: for example, on the 6th June, 1889, No. 1 engine is supposed to have made an average number of strokes throughout the whole day at the rate of 44·82 per minute. Now, as I was informed, if these pumping engines run at a greater speed than 16 or 17 strokes per minute they slip sewage to an enormous extent; it is, therefore, evident that there is something seriously wrong in the engines, or the counters are not to be relied upon.

In the one hundred days included in the foregoing table, the average number of strokes per minute was 47·275, and the volume of sewage raised, when calculated on the reduced capacity of the pumps, exceeded 12 million gallons per day. If the volume of sewage was calculated on the actual capacity of the pumps, the volume raised would have been about 24 million gallons per day.

B. L.

13, VICTORIA STREET, WESTMINSTER,
27*th May*, 1890.

STATEMENT FURNISHED TO MR. LATHAM FOR INSERTION IN REPORT.

| | Gallons. |
|---|---|
| Pumping capacity per diem of each of the engines at the Love Grove pumping-station .. .. .. .. .. .. | 7,244,000* |
| Combined pumping capacity per diem of the four engines | 28,976,000 |
| Estimated quantity of the sullage water carried by the new ovoid sewer on the flats, taking the present population at 927,740 and the sullage water at 10 gallons per head, one-third ($\frac{1}{3}$) of the water supply per head being lost by absorption, evaporation, &c. .. .. .. .. | 9,277,400† |
| Water used for flushing the ovoid sewers at Carnac Bunder and Queen's Road. This is computed on the basis that the sea-water runs into the new ovoid sewer through Carnac Bunder and Sonapore sluices daily for 10 minutes over the average level of the sullage water in the sewers up to the mean high-water level, which is 84·50 feet above Town Hall datum .. .. .. .. .. .. .. .. | 230,781 |
| Total quantity of sullage required to be raised by the pumps at Love Grove .. .. .. .. .. .. .. | 9,508,181 |

## LIST OF PLANS, ETC., SUBMITTED TO MR. BALDWIN LATHAM.

| No. | Description of Documents. |
|---|---|
| 1. | General plan showing the sewerage scheme of Bombay. |
| 2. | Plans of outfall sewer. |
| 3. | ,, main sewer, Kamatipura ovoid sewer, Queen's Road sewer, Clerk Road sewer, Ripon Road sewer, and Mint Road sewer. |
| 4. | ,, pipe sewers in the first portion of the drainage scheme. |
| 5. | ,, Fort pipe sewers. |
| 6. | ,, Mody Bay sewers. |
| 7. | ,, Queen's Road and Girgam pipe sewers. |
| 8. | ,, Agripada pipe sewers. |

* Assuming that the engines lift the full capacity of the pumps, which at present is not the case, for reasons given in Report, p. 55.

† *Vide* figures in Report, pp. 63 and 106.

No. Description of Documents.

9. Plans of pipe sewers (extension of the original scheme to Marine Lines, Arthur Road, Bellasis Road, and De Lisle Road).
10. Plan for drainage of the northern part of the Island.
11. Ventilating shafts on ovoid sewers.
12. ,, ,, pipe sewers.
13. Daily diagrams of sewage, from observations at various points.
14. Plans of pipe sewers in Kamatipura.
15. Proposed sewerage of Colaba.
16. ,, ,, Parel.
17. ,, ,, Umarkhadi.
18. ,, ,, Mazagon.
19. Design for bell-mouth junctions for the Fort, Kavasji, Patel Tank, Khetwadi, Grant Road, and Clerk Road sewers.
20. Cross-sections showing the different sizes of the sewers.
21. Details of Carnac Bunder penstocks.
22. Details of connection of the Marine Street and Elphinstone Circle drain with the Mint Road sewer.
23. ,, connection of Marine Lines, Sonapore, and Charni Road drains.
24. ,, conection of manholes on ovoid and pipe sewers.
25. ,, lampholes on pipe sewers.
26. ,, flushing chambers.
27. ,, ,, tank for the head of a house-gully.
28. ,, masonry, cast-iron and zinc ventilating-shafts.
29. ,, ,, for underground channel ,,
30. ,, gully-trap, siphon, and 2½-in. ventilating-pipes.
31. ,, house-connections.
32. ,, step-arrangements for receiving an ordinary sewage, while excluding a rush of storm-water.
33. Plans of Kamatipura old drainage.
34. Longitudinal sections of old open main drain.
35. Cross sections of old open main drain.
36. Details of connection of the old open main drain with the new main sewer.
37 ,, outlet sluices of reservoir at Love Grove.
38. Plan of storm-water reservoir.
39. Cross-sections through reservoir.
40. Plan showing drainage areas of different storm-water drains.
41. Plans and sections of storm-water drain from Haines Road to Warli.

| No. | Description of Documents. |
|---|---|
| 42. | Plans and sections of storm-water drain from the open main drain at the Clerk Road to the new proposed outfall at Warli. |
| 43. | „ „ „ from Paidhoni to Bellasis Bridge. |
| 44. | „ „ „ from Gowalia tank to old main drain. |
| 45. | „ „ „ from 12th Khetwadi Lane to 15th Khetwadi Lane. |
| 46. | „ „ „ in Ripon Road. |
| 47. | „ „ „ in Kamatipura. |
| 48. | Details of masonry, gullies, or water-entrances. |
| 49. | „ Love Grove pumping station, showing arrangements of engines, pumps, &c. |
| 50. | Details of engine house at Love Grove. |
| 51. | General plans of arrangements at Love Grove pumping-station. |
| 52. | Details of shred lifter „ „ „ |
| 53. | „ boiler house „ „ „ |
| 54. | „ cooling-tank „ „ „ |
| 55. | Designs for latrines (pail, basket, and water systems). |
| 56. | „ urinals. |
| 57. | Carnac Bunder night-soil depots. |
| 58. | Plans of the house-sullage water connections in first portion of the drainage scheme. |
| 59. | „ „ „ in Kamatipura. |
| 60. | „ „ „ in Khetwadi. |
| 61. | „ „ „ in Queen's Road and Girgam district. |
| 62. | „ „ „ in Agripada district. |
| 63. | General plans for night-soil depots. |
| 64. | Details of Clerk Road culvert. |
| 65. | Plans of Port Trust drains. |
| 66. | Plan showing the levels of the bottom of the channel in front of Love Grove sluices. |
| 67. | Plan and sections showing to the Dharavi existing and proposed water-courses. |
| 68. | Plans of outfalls of existing sewers. |
| 69. | Storm-water channel near Love Grove sluices. |
| 70. | Section of existing drain and proposed ovoid sewer in Frere Road. |

No. Description of Documents.

71. Map of Bombay, showing Mr. Aitken's scheme of drainage.
72. " " " contour of main drain, &c.
73. Plan showing sites proposed for outfall at Colaba, by Mr. Aitken.
74. " " existing drain to the native town.
75. " " " " and proposed sewers.
76. Section from Null Bazaar to Colaba reservoir.
77. Plan and section of low level sewer on flats.
78. Plan of site of Warli sluices.
79. Plan of the Mahalaxmi storm-water reservoir and surroundings.
80. Plan showing existing sewers in Fort.
81. Plan of the native town, showing the existing covered drains.
82. Map showing different sewers.
83. " " " storm-water arrangements.
84. Details of Warli sluices.
85 Map showing surface levels of the island of Bombay.
86. " sub-soil water " " "
87. Section of proposed outfall sewer from Parel Tank to Colaba, by Mr. Baldwin Latham.
88. Indicator diagrams from the Love Grove pumping-station engines.*
89. Copy of the Plan showing the Island of Bombay and the portion of land up to Kurla; scale, 20 cables to an inch.
90. Sections of ovoid sewers, showing the observations taken on 27th January, 1890.
91. Section of 15-inch pipe sewer, in Marine Lines, showing the observations on 20th February, 1890.

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92. Report on the Drainage of Bombay, by Mr. Berkley.
93. " " " Mr. Tracey.
94. " " " Mr. Aitkins.
95. " " " Major Tulloch.
96. " " " Mr. Sowerby.
97. " " " Mr. Braham.
98. " " " Dr. Blaney.
99. " " " Dr. Howlett.
100. " " " Mr. Walton.
101. Army Sanitary Commissioner's Report, with Mr. Rawlinson's endorsement.
102. Drainage Commission Report (1879).
103. Surface Drainage Report, by the Commissioner.
104. Report on the Carnac Bunder night-soil depot, by the Commissioner, (1884).

* *Vide* Plate 4.

# INDICATOR DIAGRAMS FROM SEWAGE PU

## Nº 3 ENGINE

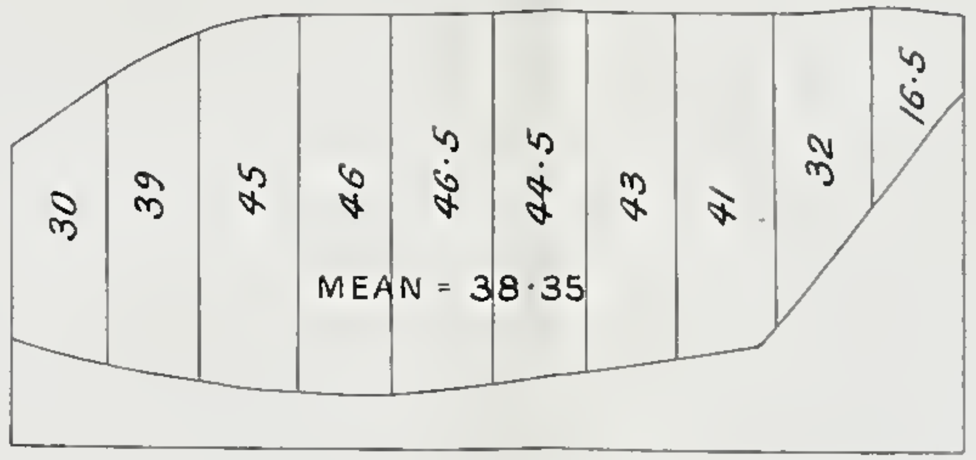
### HIGH PRESSURE CYLINDER

Scale 1/30

*TOP*

STEAM 60 LBS. REVS. 17·25  2·5 × 17·25 = 43·125

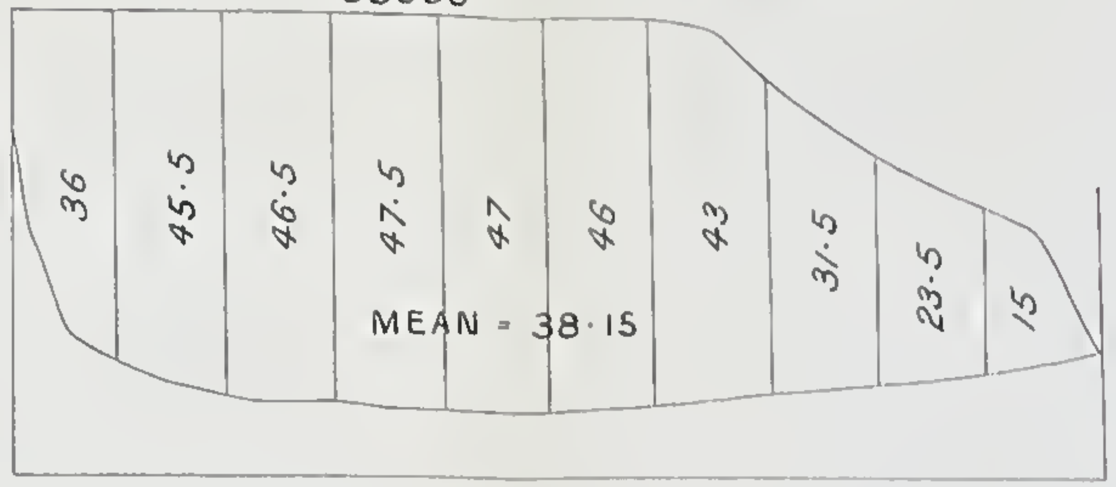
$$\frac{38\cdot35^{lbs.}\times 306\cdot7^{\square''}\times 43\cdot125^{ft.}}{33000} = 15\cdot37 \text{ H.P.}$$




*BOTTOM*

2·5 × 17·67 = 44·15  STEAM 60 LBS. REVS. 17·67

$$\frac{38\cdot15^{lbs.}\times 306\cdot7^{\square''}\times 44\cdot15^{ft.}}{33000} = 15\cdot65 \text{ H.P.}$$



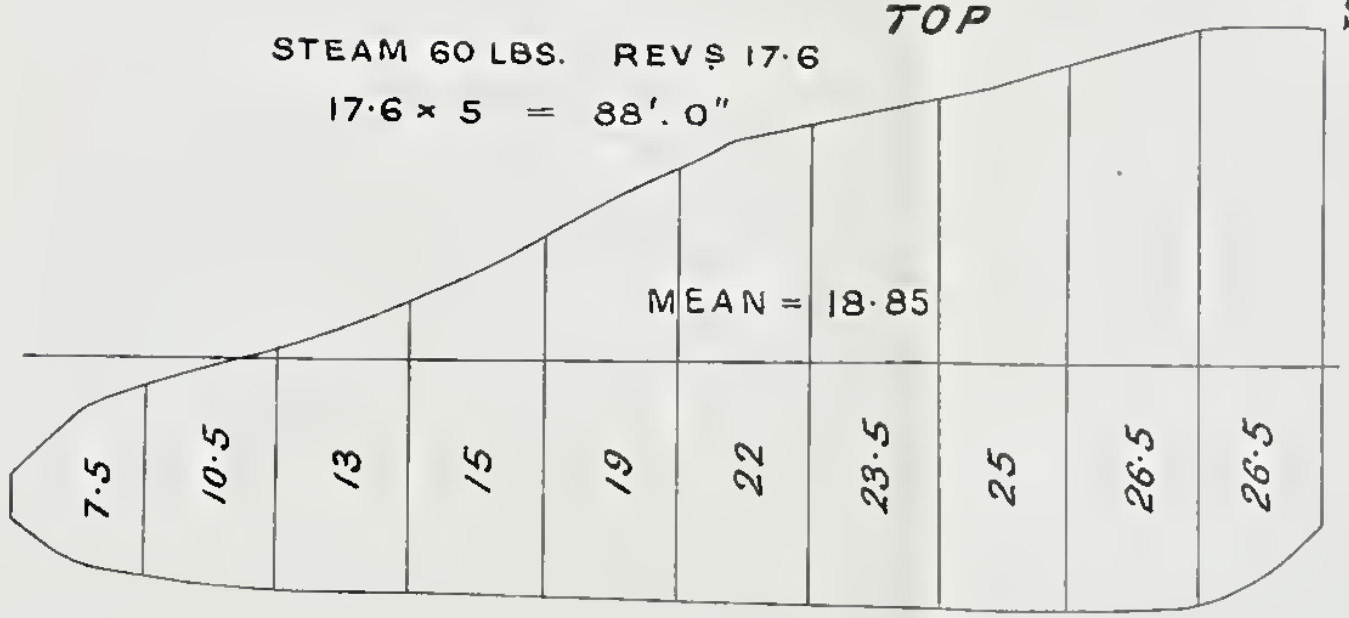

### LOW PRESSURE CYLINDER

Scale 1/12

*TOP*

STEAM 60 LBS. REVS. 17·6

17·6 × 5 = 88'. 0"

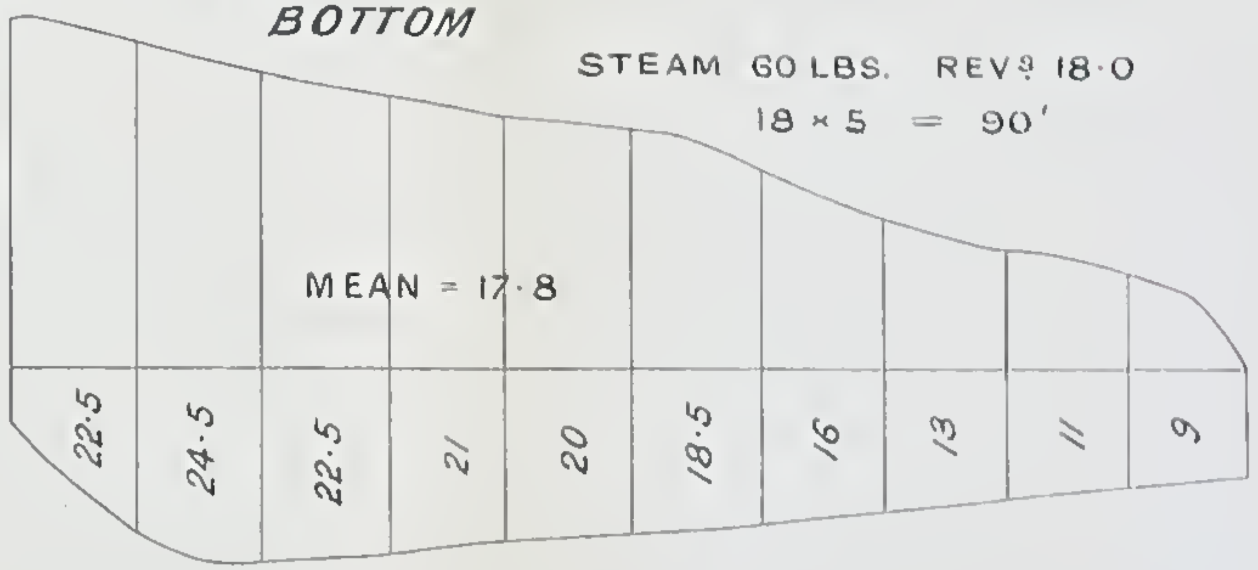



$$\frac{18\cdot85^{lbs.}\times 484\cdot6^{\square''}\times 88^{ft.}}{33000} = 24\cdot36 \text{ H.P.}$$

*BOTTOM*

STEAM 60 LBS. REVS. 18·0

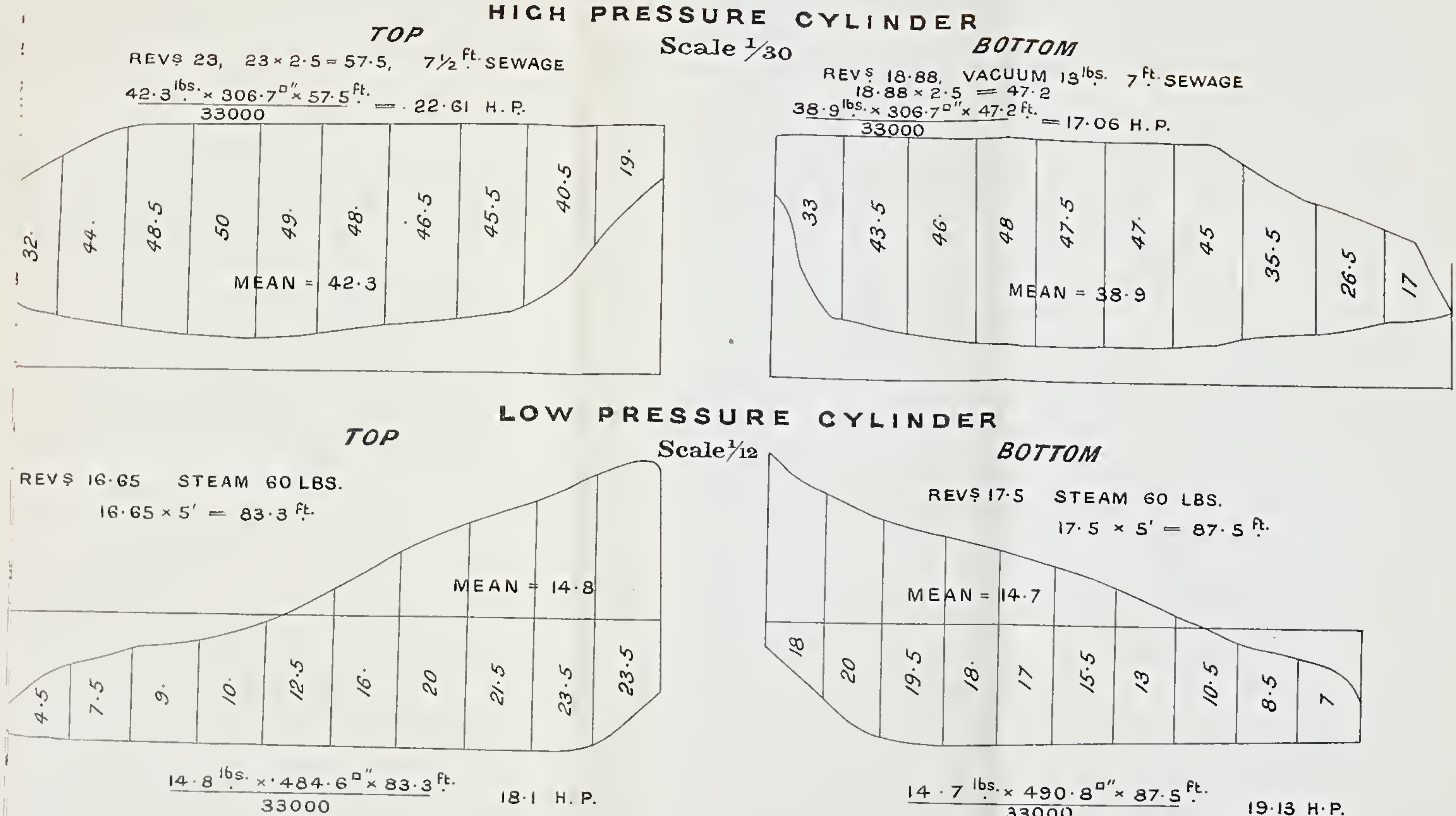
18 × 5 = 90'




$$\frac{17\cdot8^{lbs.}\times 490\cdot8^{\square''}\times 90^{ft.}}{33000} = 23\cdot83 \text{ H.P.}$$

# 'UMPING ENGINES BOMBAY.

## No. 4 ENGINE




To face p. 110.

No. Description of Documents.

105. Statement of Extraordinary Expenditure, by the Commissioner (1883–84).
106. Report of the Bombay Extension Committee.
107. Mr. White's Report on the removal of kachra to Kurla.
108. Report on the Drainage of Marine Lines, by a Committee appointed by Government, with Dr. McRury's letters.
109. Bombay Meteorological Reports, from 1846 to 1862, and 1864 to 1888–89.
110. Tide Tables for the Port of Bombay, 1890.
111. Chart of the West Coast of the Bombay Presidency.
112. Twenty-four Diagrams, Nos. 268 to 291, of the Tidal Registrations at the Apollo Bundar during 1889.
113. Administration Reports of the Bombay Municipality, from 1878 to 1888–89.
114. Executive Engineer's Report (with plans and estimates) on the sewerage of Colaba.
115. Executive Engineer's Report (with plans and estimates) on the sewerage of Parel, Umarkhadi, and Mazagon district.
116. File of Acting Army Sanitary Commissioner's Reports.
117. Drainage Commission Report, and Mr. Rawlinson's Report on the Drainage of Bombay, sent by Mr. Hughes, Secretary to Government, P.W.D.
118. List of Counter Readings taken of the Engines at the Love Grove pumping-station, from May to August, 1889.
119. Return of Births and Deaths from the Health Officer.
120. Samples of Kachra " "
121. Float experiments by Mr. Raghunath Putlaji, Head Surveyor Bombay Port Trust Engineer's Office.
122. Census Report, 1881.

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## STATEMENTS SUBMITTED TO MR. LATHAM.

1. Details of ovoid sewer from Carnac Bunder Road to Love Grove pumping-station.

   Branch sewers :—

   (1) From Town Hall to the junction of Shek Memn Street.

   (2) From Queen's Road to the junction of Khetwadi Tenth Lane.
2. Details of pipe sewers, first portion of drainage scheme.
3. Details of pipe sewers, Queen's Road and Girgam drainage scheme.
4. Details of pipe sewers, Parel, Mazagon, and Umarkhadi districts.

| No. | Description of Documents. |
|---|---|
| 5. | Total lengths of ovoid and outfall sewers. |
| 6. | Statement showing the size, lengths of different sizes, gradients, discharging capacities, velocities, and populations served by the different portions of the main sewers (ovoid). |
| 7. | Ditto, ditto, by the Hornby Road and Mint Road ovoid sewer, the Queen's Road ovoid sewer, the Kamatipura ovoid sewer, the Clerk's Road ovoid sewer, the Ripon Road ovoid sewer. |
| 8. | Summary of the lengths of the pipe sewers of different diameters. |
| 9. | Lengths of the pipe sewers of the different districts. |
| 10. | Size, lengths, gradients, and velocities of the pipe sewers in the various streets, included in the first portion of the drainage scheme. |
| 11. | Ditto, ditto, included in the Fort pipe-sewer scheme. |
| 12. | Ditto, ditto, included in the Mody Bay pipe-sewers scheme. |
| 13. | Ditto, ditto, included in the Queen's Road and Girgam drainage districts. |
| 14. | Ditto, ditto, included in the Agripada districts. |
| 15. | Ditto, ditto, included in the pipe-sewers extension of the original scheme. |
| 16. | Scheme for drainage of the northern parts of the island of Bombay, if made to fall to present pumping-station at Love Grove. |
| 17. | Ventilating shafts on ovoid sewers. |
| 18. | ,, ,, pipe sewers. |
| 19. | Manhole and sewer inspection establishment. |
| 20. | Statement showing the establishment required for cleaning the pipe sewers and ovoid sewers. |
| 21. | Engines at Love Grove pumping-station. |
| 22. | Total daily discharge of sewage, calculated from observations in outfall sewer, taken daily from 6 a.m. to 6 p.m. |
| 23. | Letter to the Municipal Commissioner regarding the capacity of the ovoid sewers on flats near Love Grove pumping-station. |
| 24. | Statement showing the acreage and populations served by ovoid sewers of different sizes. |
| 25. | Statement of observations taken in ovoid sewers 27th Jan., 1890. |
| 26. | Statement of observations taken in 15-inch pipe sewer in Marine Lines on 20th February, 1890. |
| 27. | Statement showing the time the tides in Bombay Harbour were below various levels, in the months of June, July, and August, 1889. |
| 28. | Statement showing various surface water drainage areas of Bombay. |

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